COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

July 1955

Aerial view of Saguaro Steam Station, Arizona Public Service Co.

Water Conditioning for Initial Boiler Operation

Training Engineers for Nuclear Engineering Work

Monotube Boiler in 1112 F Steam Power Plant

International Combustion Conference

S.S. WORLD GLORY

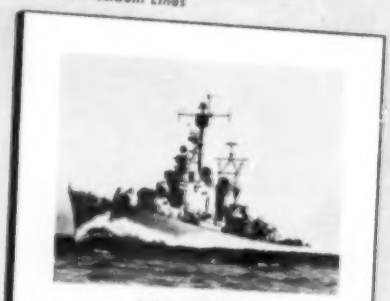
North American Shipping and Trading

S.S. PRESIDENT CLEVELAND

American President Lines

S.S. VENORE

Ore Steamship Company



U.S.S. MITSCHER

U.S. Navy

S.S. ATLANTIC SEAMAN

Philadelphia Tankers, Inc.

S.S. WILFRED SYKES

Inland Steel Company

S.S. NORTH DAKOTA

The Texas Company

S.S. OLD COLONY MARINER

Maritime Administration

DISTINCTIVE

...and powered by C-E Boilers

Distinctive for various reasons, these ships are also notable for their steam power plants, which include boilers designed for the highest pressure and the highest temperature used in marine service, as well as the first controlled circulation boilers in a U.S. ship "of the line."

B-782-A

COMBUSTION ENGINEERING

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT FOR MARINE AND STATIONARY APPLICATIONS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 1**

July 1955

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BPA

Printed in U. S. A.

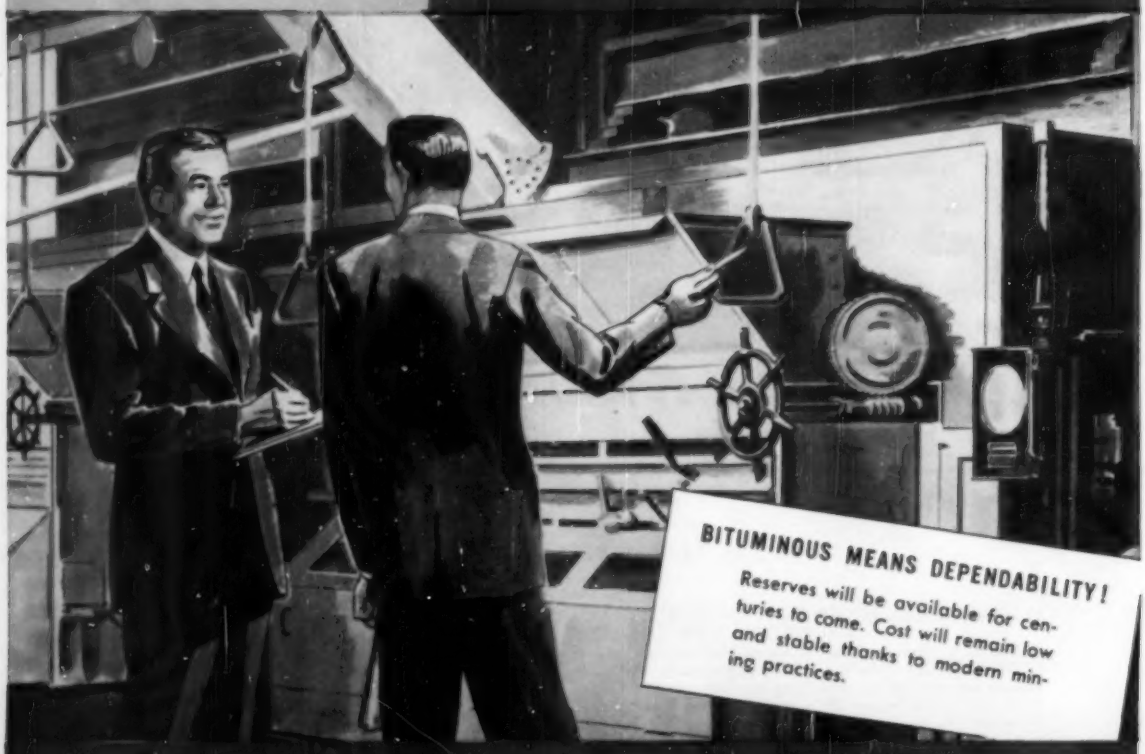
Are you now using the most efficient coal for your purpose?

LET OUR TECHNICAL SERVICE ADVISE YOU!

No two plants are alike—design and equipment characteristics make the difference. That's why it's so important to consider *kind* and *size* when selecting a coal for your particular burning equipment. The B&O Technical Service is prepared to study your specific problem and help you choose the correct coal. Here's what our service does for you:

- outlines Bituminous coals available for your plant.
- discusses the merits of these coals.
- establishes current and predicts future relative values of these coals.
- determines the best coal for your system.
- suggests the most efficient way to burn this coal.
- supplies case histories of actual savings in fuel costs.

Ask our man! Write:
COAL TRAFFIC DEPARTMENT
BALTIMORE & OHIO RAILROAD
BALTIMORE 1, MARYLAND



BITUMINOUS MEANS DEPENDABILITY!

Reserves will be available for centuries to come. Cost will remain low and stable thanks to modern mining practices.

Baltimore & Ohio Railroad

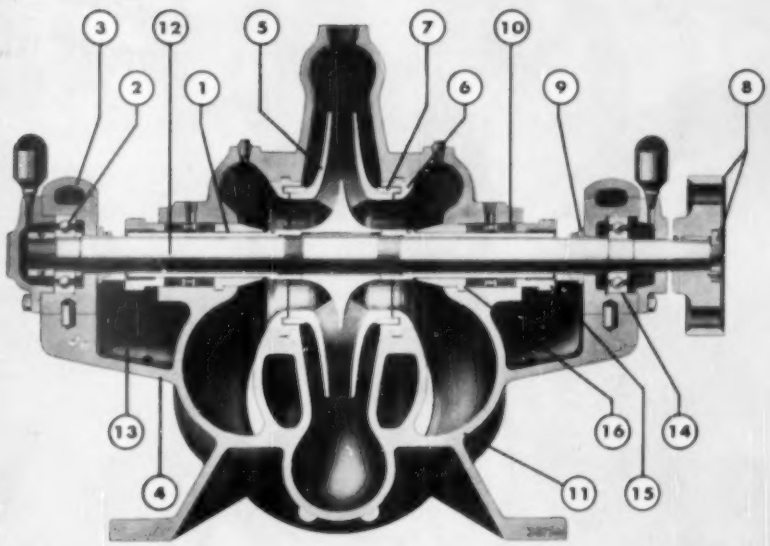
Constantly doing things—better!

BITUMINOUS COALS FOR EVERY PURPOSE

DE LAVAL

SINGLE STAGE CENTRIFUGAL PUMPS

for dependable industrial service



Labyrinth wearing rings minimize leakage...maintain high efficiencies

Labyrinth rings used in these De Laval pumps retard flow of water through labyrinth passage.

Flat rings showing relatively unimpeded flow of water.

(1) **Shaft Sleeves** are screwed on, to abut the impeller and make a water-tight joint. Sleeve expands freely and independently of shaft when temperatures change. There is no tendency to buckle.

(2) **Thrust Bearing** locates rotor axially.

(3) **Bearing Caps** easily removable for maintenance.

(4) **Bearing Brackets** scraped to lining bars for perfect alignment.

(5) **Impeller** hydraulically balanced, finished on all surfaces.

(6) **Labyrinth Wearing Rings** held accurately in machined grooves in both case and cover.

(7) **Impeller Wearing Rings** threaded on impeller, opposite to rotation.

(8) **Flexible Coupling** ground on all exposed surfaces and statically balanced, complete coupling supplied, pump half mounted on taper so that it can be easily removed. Check nut locks coupling on taper.

(9) **Deflector** keeps water out of bearing.

(10) **Stuffing Boxes** extra deep; lantern rings for water sealing.

(11) **Pump Case** horizontally split; machined to limit gages.

(12) **Steel Shaft** ground to limit gages.

(13) **Drip Boxes** large; provided with drain openings.

(14) **Radial Bearing** free to move axially, thus avoiding temperature strains.

(15) **Glands** split horizontally.

(16) **Protecting Bushings** renewable.

You can count on the performance of the De Laval Single Stage Centrifugal Pumps because they are precision-made to high manufacturing standards and incorporate the many quality design features shown in the cross-section.

They operate at high or low speeds, at high or low heads...with maximum efficiency.

For example, De Laval G, I and K Single Stage Double Suction Pumps have a capacity range of 175 gpm to 6,000 gpm, and heads to 300 feet. They are available in sizes ranging from 4" suction and 3" discharge to 14" suction and 12" discharge. Write for Bulletin 1002.

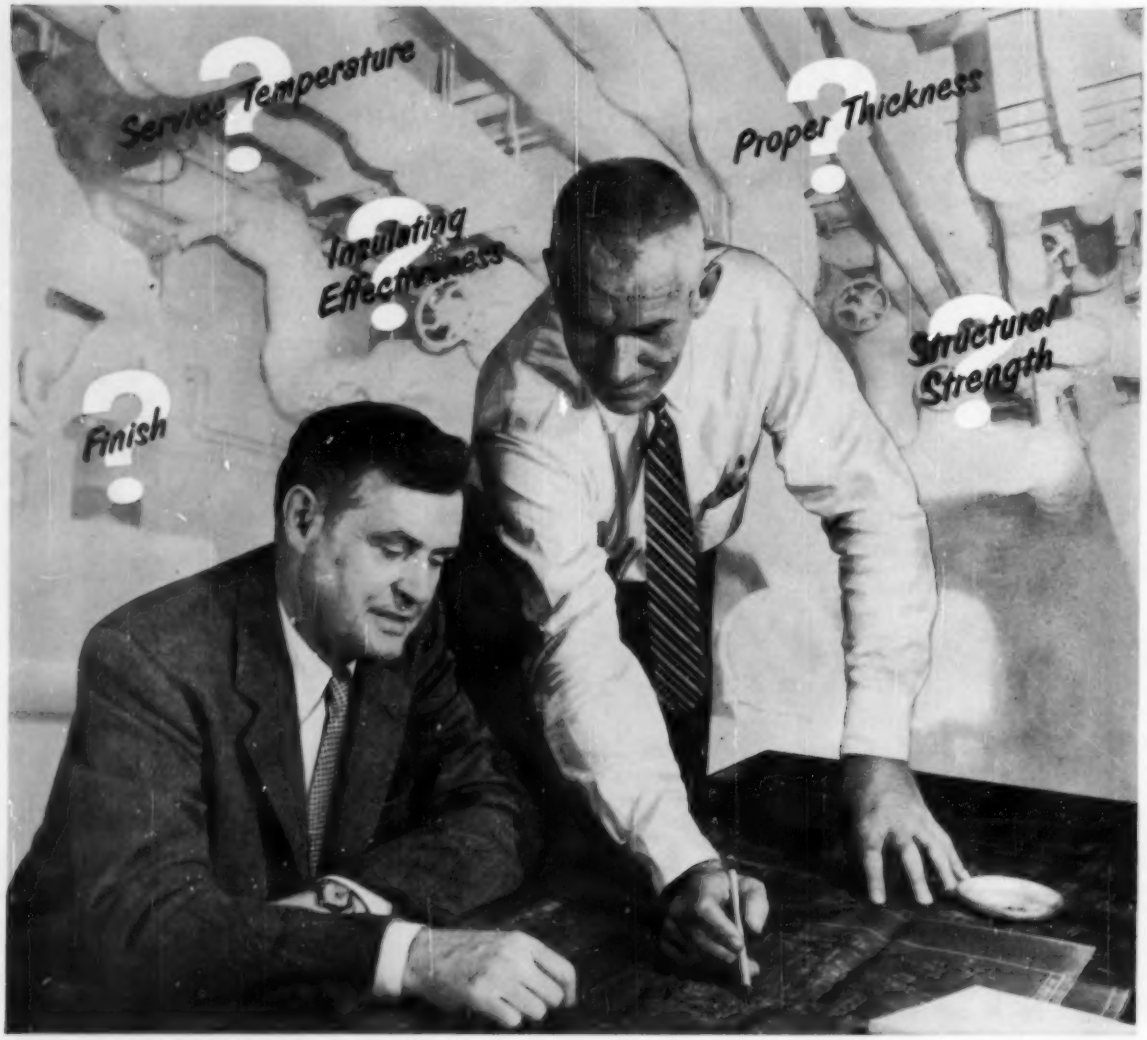
DeLaval also furnishes larger centrifugals for capacities up to 70,000 gpm.

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY

886 Nottingham Way, Trenton 2, New Jersey

DL 188



Old hands at solving new insulation problems

Your **J-M Insulation Contractor** knows the answers that give you a better, more economical job

To be sure of getting the most efficient insulation for your plant or equipment, see the man with the world's most complete engineering and application service. He's your J-M Insulation Contractor who brings to every job the accumulation of Johns-Manville's 95 years' experience in the thermal insulation field.

J-M Insulation Engineers work hand in hand with J-M Insulation Contractors. Together they have achieved outstanding results with some of the most intricate insulation problems . . . of every type and size—in every industry.

J-M Insulation Contractors provide a complete selection of Johns-Manville quality materials. They will choose from their own stocks the best insulation for your conditions within the broad temperature range extending from minus 400F to plus 3000F.

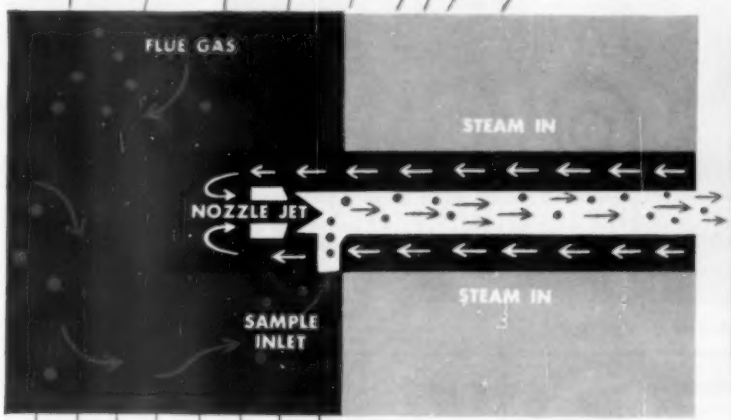
Skilled application is a major contribution your J-M Insulation Contractor brings to every insulation job. His skilled mechanics have mastered the latest application techniques that assure you top-quality installation . . . give maximum operating economy and lower maintenance costs.

For undivided responsibility on all your insulation requirements, call your J-M Insulation Contractor. Write for the name of the one nearest you. Address Johns-Manville, Box 60, New York 16, New York. In Canada, Port Credit, Ontario.

Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION

NEW DIMENSIONS



in Gas Sampling

NEW SAMPLING SYSTEM OPERATES ON STEAM!

The new Hays Gaspirator* System is designed especially for difficult gas sampling problems involving high dust loading and high temperatures. It now permits accurate O_2 measurement, previously impossible in many applications.

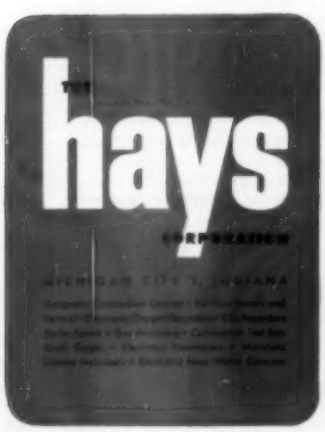
This gas sampling system uses steam to obtain a continuous, clean sample. Suction which is created by the jet nozzle draws the sample in, where it is mixed with the steam. The steam is then condensed. Condensate and entrained solids drop down, and the sample is forced through the analyzer under pressure.

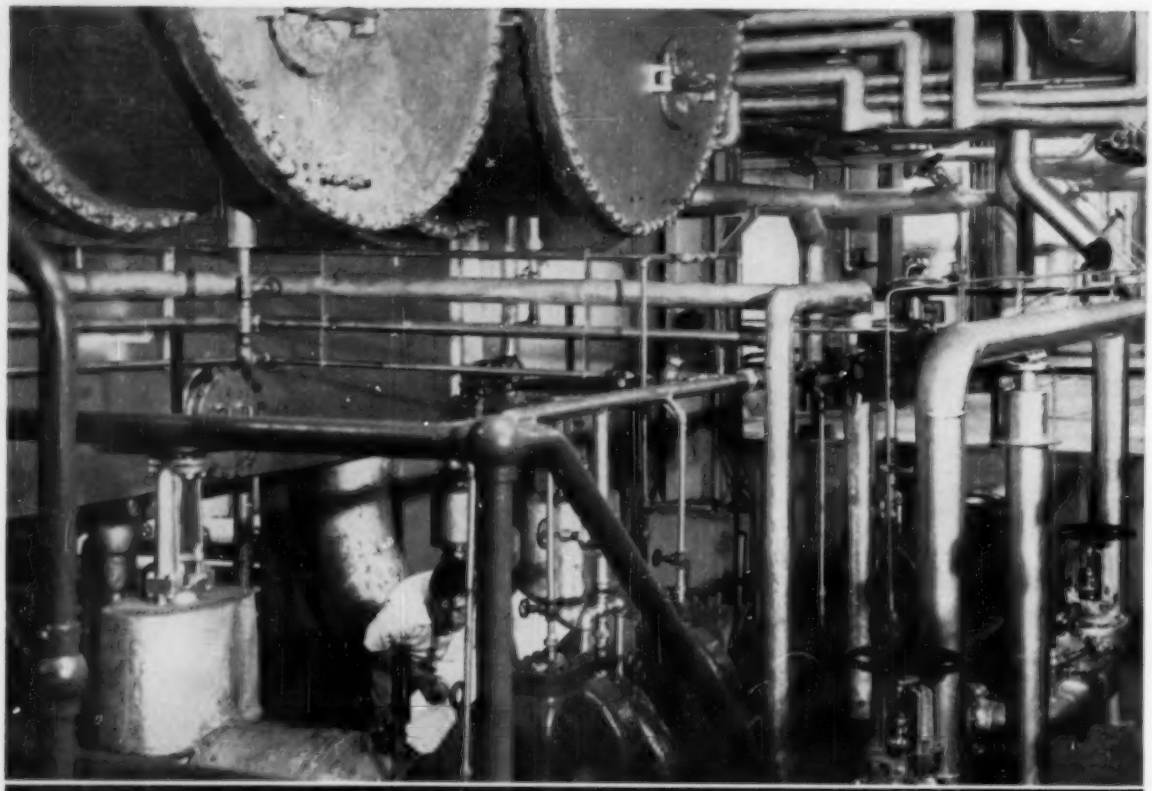
Hays, in the field of gas analysis for more than fifty years, developed the Gaspirator for use with their Magno-Therm Analyzer.

This analyzer, which operates on the paramagnetic principle, has for years been accepted as the leader in the field of O_2 measurement. Hundreds of companies are using the Magno-Therm and Hays electronic recorders very successfully in boiler plants and on process furnaces as a combustion guide, in regeneration of catalysts in refineries and in many other process applications.

For further details write for Bulletin 55-829-56.

*Patents pending.





DEAERATING CONDENSER EXCEEDS GUARANTEED PERFORMANCE

	guarantee	actual performance
Condensate depression	0	0
cc of oxygen per liter in condensate	0.01	no measurable amount

This 50,000 sq. ft. steam surface condenser was installed by Lummus for Carolina Power & Light Company, Goldsboro Steam Electric Generating Plant, Goldsboro, N. C., Ebasco Services, consulting engineers. The unit is a deaerating type condenser of Lummus' patented design, serving a 66,000 KW turbine.

After three years of operation, it is still meeting and exceeding the original performance guarantees, as tabulated above, under all conditions of operation.

The unit was designed to condense 400,000 pounds/hr. of exhaust steam from the turbine at 2.10" Hg. abs. and deaerate the condensate. In addition to the condensate the unit must deaerate 50,000 pounds/hr. of drains from feed-water heaters and 100,000 pounds/hr. of cold make-up water at ambient temperature. The drains and make-up water enter the condenser above the tube bank and are deaerated in the Lummus patented deaeration section. Tests run with supersaturation of air in the cold make-up were handled with complete removal of oxygen and other dissolved gases without any unbalancing of the system.

Lummus-designed equipment gives results of this caliber consistently. May we sit in with your engineers on the project coming up?

THE LUMMUS COMPANY, Heat Exchanger Division, 385 Madison Avenue, New York 17, N.Y. • Atlanta • Boston Chicago • Cincinnati • Cleveland • Dallas • Denver Detroit • East Chicago (Indiana) • Houston • Kalamazoo Kansas City • Los Angeles • Minneapolis • Nashville New Orleans • Newton (Iowa) • Niskayuna (New York) Omaha • Pittsburgh • Salt Lake City • San Francisco Springfield (Mass.) • Syracuse • Toledo • Wayne (Pa.) Athens • Buenos Aires • Caracas • The Hague • Lima London • Mexico City • Montreal • Paris • Rome • San Juan

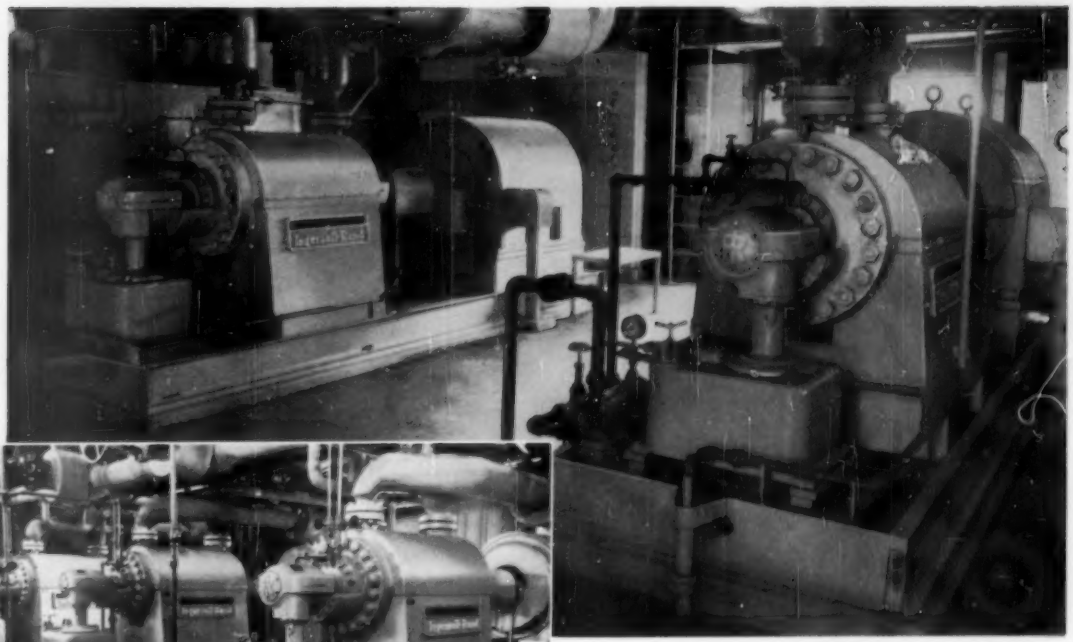
Fabricated Piping Division Plant at East Chicago, Ind.

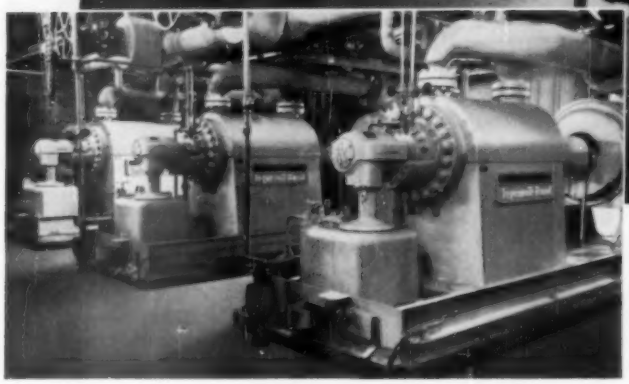
Steam Surface Condensers • Evaporators • Extraction Bleeder Heaters • Steam Jet Air Ejectors • Steam Jet Refrigeration • Barometric Condensers • Heat Exchangers for Process and Industrial Use • Process Condensers Pipe Line Coolers.

LUMMUS

THE LUMMUS COMPANY, HEAT EXCHANGER DIVISION • 385 MADISON AVENUE, NEW YORK 17, N. Y.

8 I-R BOILER FEED PUMPS serve large Southwest utility





... and 3 MORE are on order!

ONE good pump deserves another. And so it grows—the record of repeat orders for I-R pumps.

Here, for example, is a large Southwest utility where the consulting engineers specified and installed *eight* Ingersoll-Rand "double-case" boiler feed pumps and ordered three more—all within a four year period. What better proof of satisfactory on-the-job-performance!

The first three CHTB pumps, shown in the smaller photo and installed in 1949, are 7-stage units rated 537 gpm at 929 psig serving two 18,750 kw generating units. The two additional CHTBs illustrated, installed in 1951, are each rated 1090 gpm, 906 psig, supplying 50,000 kw of generating capacity. At another plant in this utility's system, three I-R boiler feed pumps, rated at 1440 psig, are installed on the present 100,000 kw unit and three more are on order for a 156,000 kw addition planned. They will be rated 1545 gpm, 1918 psig.

When it comes to high pressure boiler feed—or any *other* power plant pumping problem – make sure of service-proved performance by specifying Ingersoll-Rand. Your I-R representative will be glad to serve you in any way.

10-103

Ingersoll-Rand

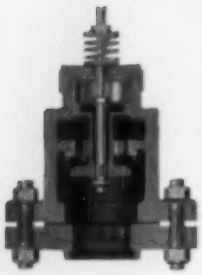
CAMERON PUMP DIVISION

11 BROADWAY, NEW YORK 4, N. Y.

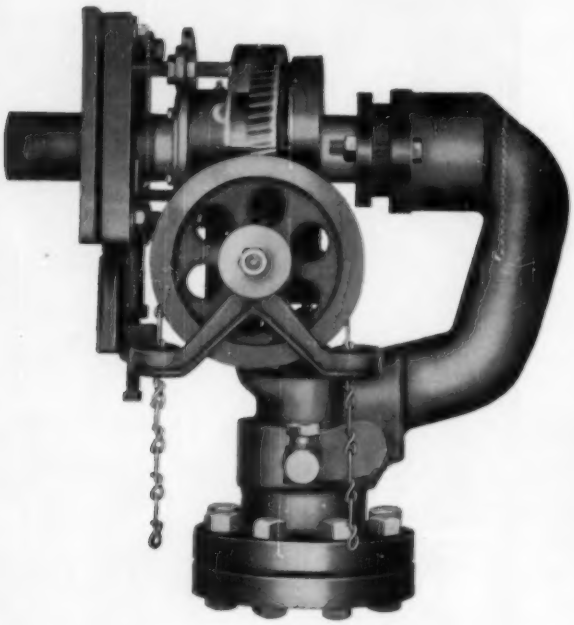
COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO-BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • DIESEL AND GAS ENGINES

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness.



Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain *steam tight* because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.

Philadelphia Electric Specifies Stainless-Clad Steel Again!

Eight stainless-clad steel hoppers and feeder pipes at the Delaware Station were specified to assure long, maintenance-free service life.

With a single exception, all of Philadelphia Electric Company's recent installations of interior coal handling equipment from the bunker to the boiler, in both new installations and replacements, are of stainless-clad steel.

In the summer of 1953, two new boilers were added at the Delaware Station. Because of the ability of stainless-clad steel to withstand the abrasive and corrosive action of coal at the key points of bunker noses, hoppers, chutes and feeder pipes, as demonstrated in the Southwark and Chester Stations, these two boilers were fitted with stainless-clad hoppers and pipes. Now, in the second year of operation, station engineers report that no hangups or troubles of any sort have been experienced.

Stainless-clad steel—a layer of stainless steel integrally bonded over the entire surface of a strong, low cost carbon steel backing plate—has low initial cost, means minimum operating and maintenance charges. Its smooth surface reduces hangups, and with hard use develops a highly polished finish. Every installation of clad steel coal handling equipment examined to date shows no measurable loss of gage even after as much as 9 and 12 years of service.

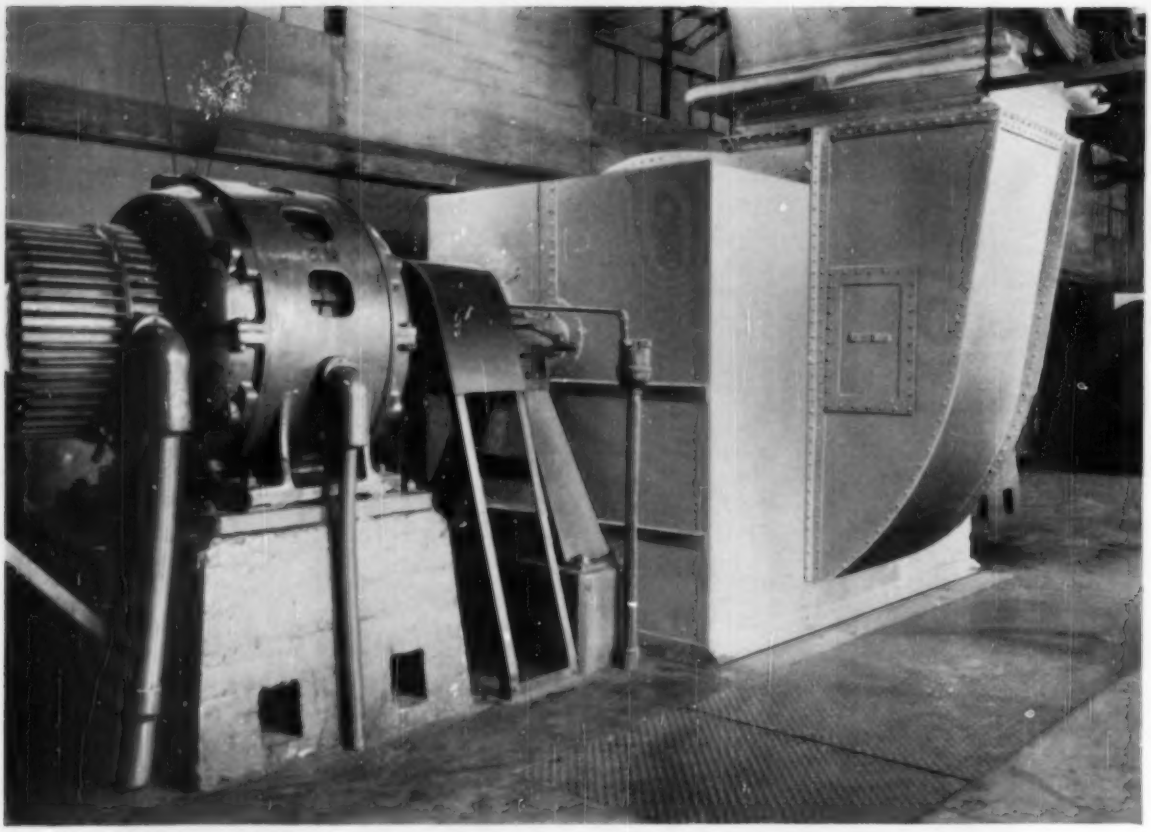
If you would like detailed information, write for Bulletin 740. In addition, our Technical Service Department is available to work with your equipment builders and engineers in putting stainless-clad steel to work for you. If you would like the names of qualified equipment builders, write to the Manager, Marketing Service, 684 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

LUKENS

STAINLESS-CLAD STEELS
FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

PRODUCER OF THE WIDEST RANGE OF TYPES AND SIZES OF CLAD STEELS AVAILABLE ANYWHERE



"Buffalo" Induced Draft Fan Installed in 1925

WHERE LONG-WINDEDNESS is a virtue!

The place where long-windedness is a prime virtue is in your boiler draft equipment. While the everlasting draft fan is yet to be invented, it is certainly true that the *longer* a fan can stand up under the beating of draft service, the more money you're saving.

That's why we've always concentrated on building long life into "Buffalo" Fans. Consider these "Q" Factor* features that explain the number of 30-year "Buffalo" Fans still on the job:

- Heavy steel plate blade and housing construction to stand heat and erosion.
- Low rotor scrubbing velocities, due to efficient modified backward curved blades.
- Strong rotor with stiff center plate — massive hub.
- Oversize alloy steel shafts with integral thrust collars.
- Low bearing pressure and large oil reservoir.
- Quick-opening access doors and removable bolted, sectional housing.
- Stable performance under widely varying load conditions.

The "Buffalo" Draft Fan you buy today embodies the finest and latest features for long life, performance and economical maintenance developed in our 78 years. It will pay you to write for Bulletin 3750 today and get all the facts.

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

"Buffalo"

BUFFALO FORGE COMPANY

170 MORTIMER STREET BUFFALO, N. Y.

PUBLISHERS OF "FAN ENGINEERING" HANDBOOK

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

Sales Representatives in all Principal Cities

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

why soot is no problem... with the Ljungstrom® Air Preheater

Soot is no problem with the Ljungstrom. Clinging soot or slag is loosened by normal expansion and contraction of the preheater . . . and most of it is blown away by the high-velocity gas streams. What remains is removed by superheated steam or compressed air, fired from oscillating soot blowers, while the Ljungstroms are in operation.

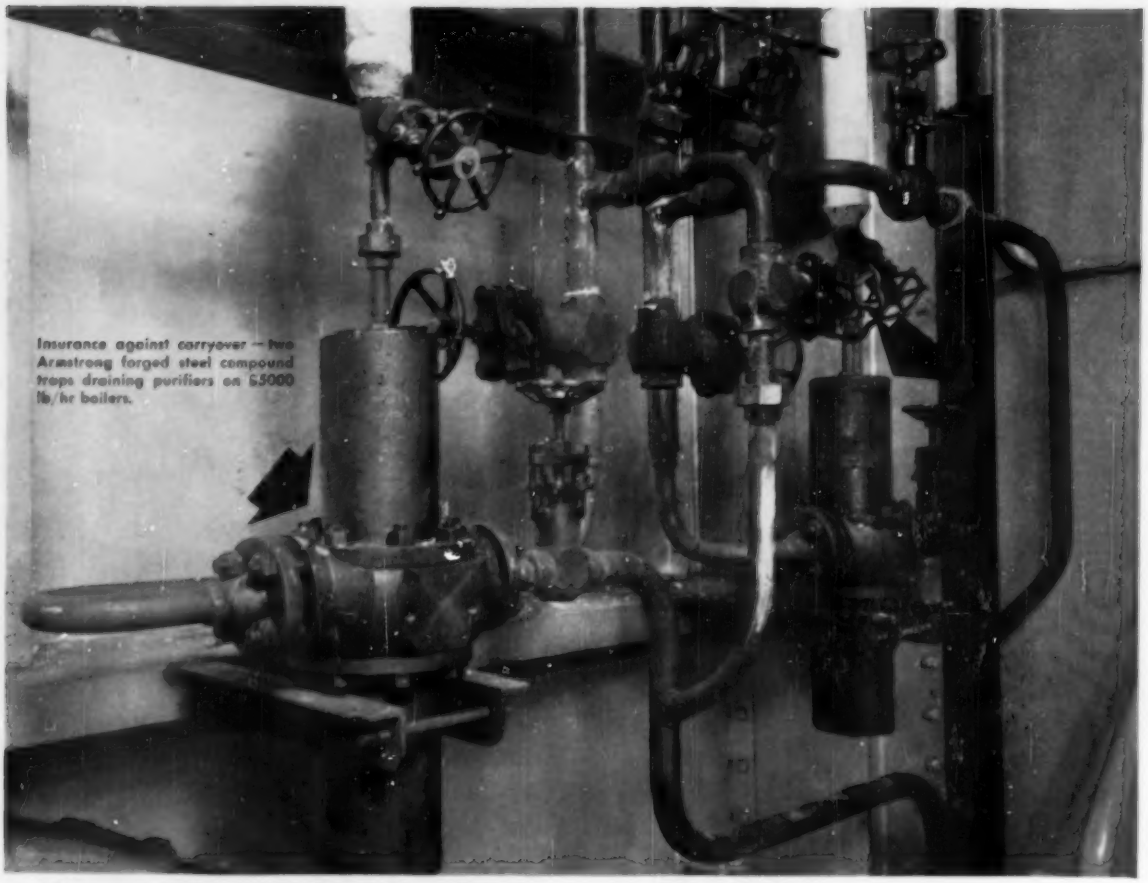
What's more, moderate deposits on the Ljungstrom heating surface have no effect on preheating. For, with the Ljungstrom, heat need not pass through a film-coated wall — but is simply absorbed by a heating surface and *released from the same surface.*

Get all the details on why the Ljungstrom is easier to clean and maintain . . . maintains higher boiler efficiencies. They're in the new, 38-page reference manual, "Ljungstrom Air Preheaters." Write for your free copy, today!

Advantages of the Ljungstrom Air Preheater

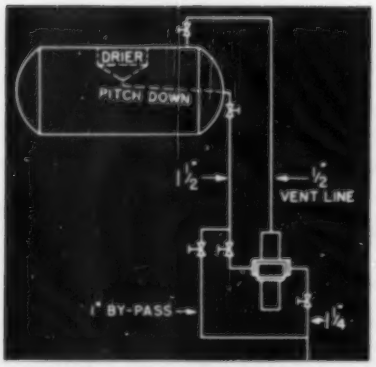
- Size for size, recovers more heat than any other type.
- Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.
- Eliminates cold spots . . . keeps corrosion to a minimum.
- Easier, faster to clean and maintain.
- Requires far less supporting steel and is quickly erected.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.



Insurance against carryover — two Armstrong forged steel compound traps draining purifiers on 65000 lb/hr boilers.

How to Insure Positive Drainage of Purifiers, Large Separators and Other Big Units . . .



Automatic, dependable drainage of steam drier in industrial power plant with Armstrong compound steam trap.

● When you run up against a carryover or condensate load too large for ordinary traps to handle safely, Armstrong Compound Steam Traps are an ideal answer. They provide automatic, dependable drainage of loads up to 240,000 lbs/hr at 600 lbs. pressure. They have been thoroughly proved in service on purifiers, separators, driers, storage type hot water heaters, evaporators, vacuum pans and other large units.

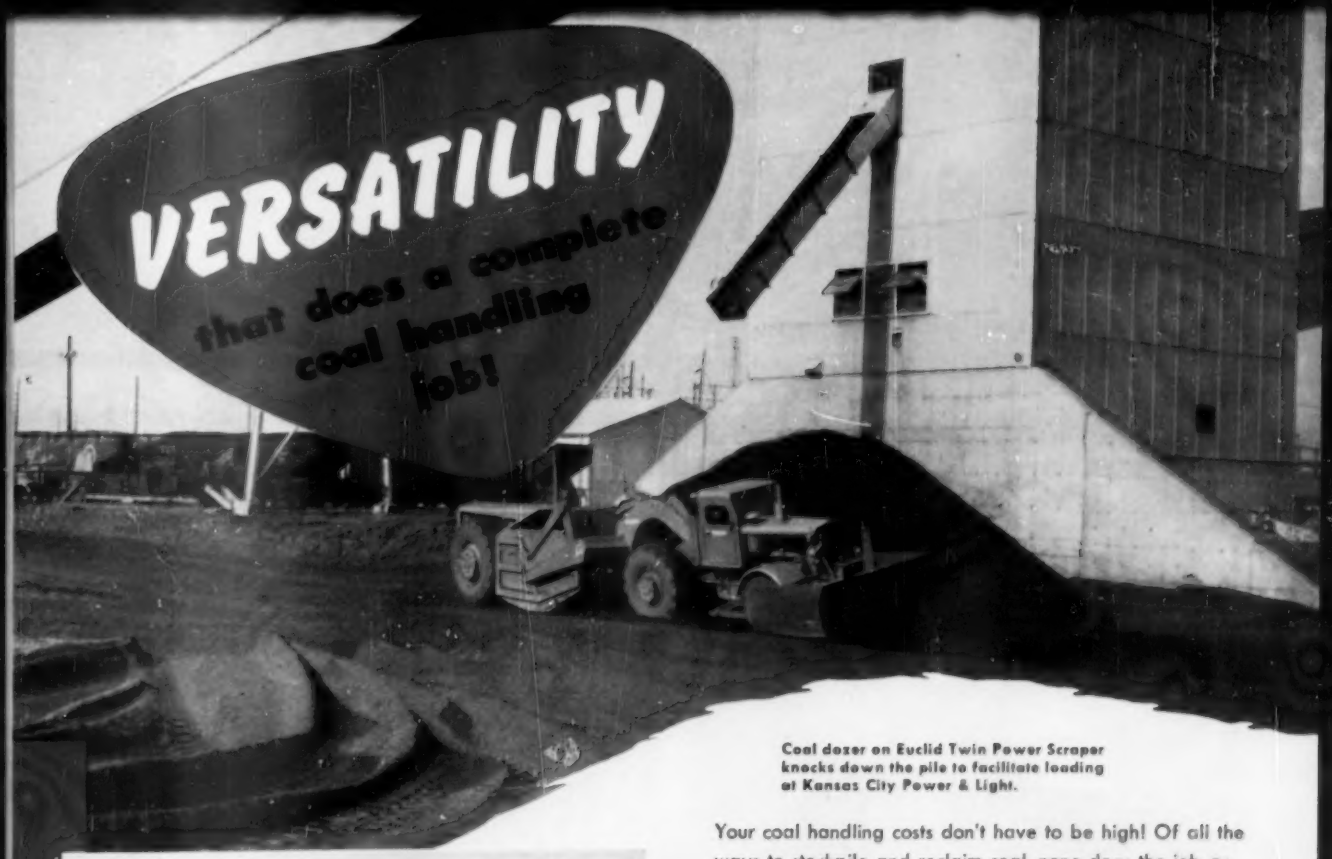
Exceptionally high capacity in a relatively small trap is accomplished by a large piston-operated discharge valve controlled by a standard Armstrong inverted bucket trap mechanism. Cast semi-steel and forged steel models are available with 1", 2" and 3" pipe connections. Size, price, simplicity of mechanism, quality of materials and ease of installation are all in their favor.

ASK FOR BULLETIN 215

. . . contains complete physical data, prices and installation notes. Call your local Armstrong Representative or write: Armstrong Machine Works, 814 Maple St., Three Rivers, Michigan

STEAM TRAPS FOR EVERY REQUIREMENT — APPLICATION ENGINEERED

ARMSTRONG STEAM TRAPS



Coal dozer on Euclid Twin Power Scraper knocks down the pile to facilitate loading at Kansas City Power & Light.

"Twin" Scraper dumps its big load . . . spreads . . . and compacts on the fly!

The "Euc" maintains a well-drained, compacted pile . . . self loads for storage or haul to the plant.

Your coal handling costs don't have to be high! Of all the ways to stockpile and reclaim coal, none does the job as efficiently and completely as the Euclid Twin-Power Scraper.

The "Twin" is completely self-loading in loose, compacted, wet or frozen coal. It builds, raises or extends a well drained and compacted stockpile . . . carries big loads at speeds up to 30 m.p.h. Using Euclid Twin-Power Scrapers for coal handling is more economical and a great deal more flexible than permanent cranes and conveyors — from both original investment and operating standpoints. The "Twin" method costs less per ton handled — as compared to other equipment — because of the speed, capacity and versatility of these "Eucs".

Kansas City Power & Light Co. uses a Euclid "Twin" at its big Hawthorn station and is well satisfied with the high production and low maintenance obtained. Installation of a coal dozer further increases the scraper's versatility by enabling the "Euc" to dress edges of the stockpile, knock down loose, steep piles at the delivery area, and clean up at the dumping hoppers.

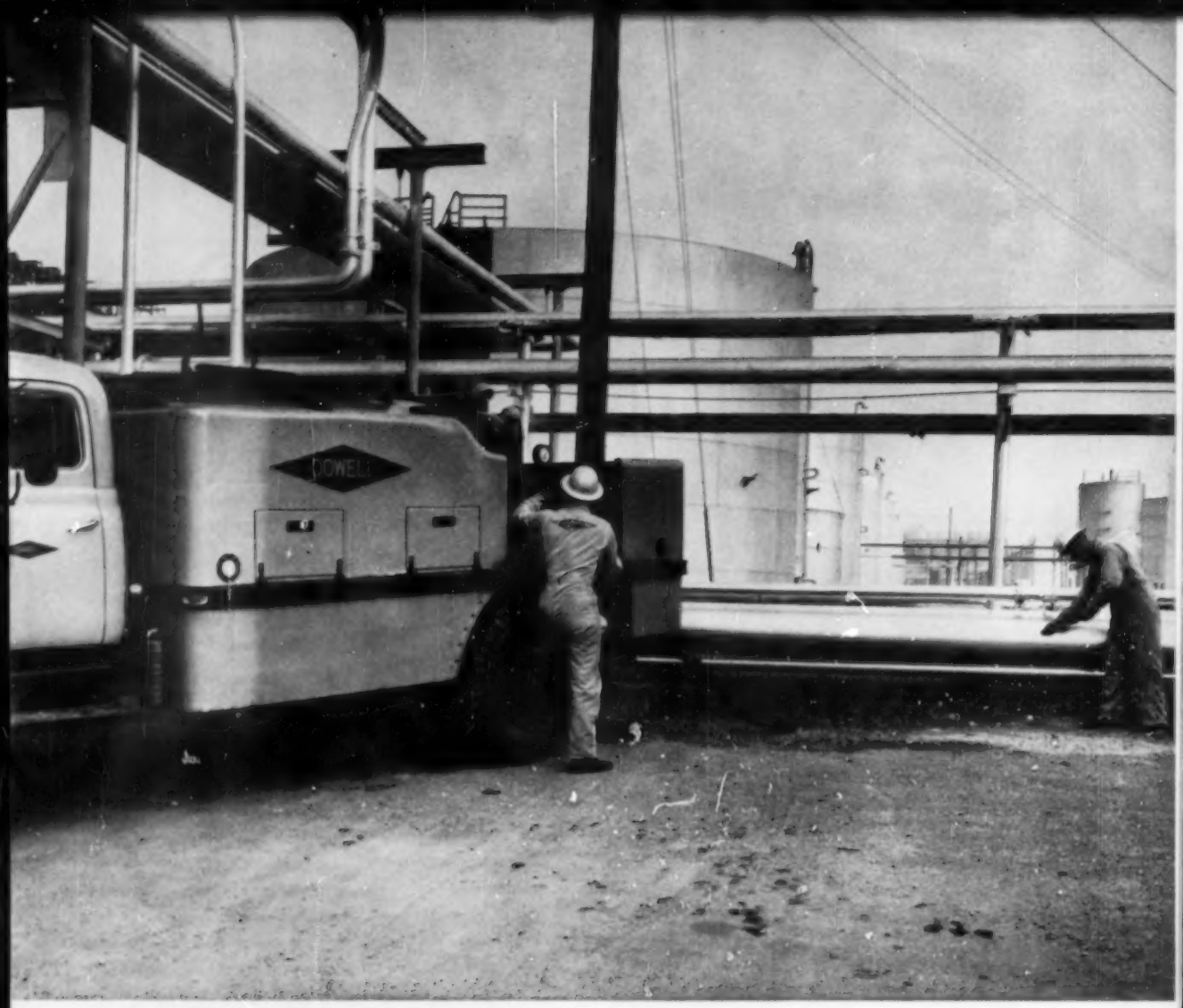
Many other industrial plants and public utilities are cutting their coal handling costs with Euclid Twin-Power Scrapers. There's a good chance your Euclid Distributor can show you the way to lower costs, too!

EUCLID DIVISION GENERAL MOTORS CORPORATION, Cleveland 17, Ohio

Euclid Equipment

FOR MOVING EARTH ROCK COAL AND ORE

GM GENERAL MOTORS



CHEMICAL CLEANING SAVED COSTLY LINE REPLACEMENT

After mechanical methods failed, DOWELL solvents removed thick scale from piping, restoring million-gallon capacity

During an oil refinery's annual turn-around, three weeks were spent attempting to clean a 20-inch water disposal line by mechanical methods. Each attempt failed to remove the scale, which ranged from 6 to 14 inches in thickness. Then—only seven days before the plant was scheduled to resume operations—Dowell was called. Dowell engineers used chemical solvents to restore the line's original capacity of 1,300,000 gallons of water per day. This job, which avoided a costly line replacement, took just six days.

Most Dowell jobs are completed within a few hours. Many lines have been cleaned without being taken out of operation at all. More time and expense are saved, too, because Dowell solvents are introduced through regular connections, avoiding costly dismantling and digging up of buried lines.

Then, too, Dowell solvents are designed to clean the *entire line*—bends, elbows, valves and any other hard-to-reach sections. Whenever the scale encountered makes it necessary, Dowell supplements chemical cleaning with pipe line pigs and jet moles.

For the best solution to your industrial cleaning problems, call your nearest Dowell office. Or write Dowell Incorporated, Tulsa 1, Oklahoma, Dept. G-25.

chemical cleaning service for industry

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES

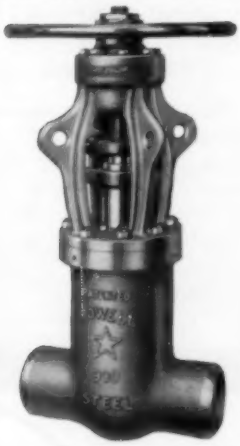
. . . THE COMPLETE QUALITY LINE . . . POWELL VALVES . . . THE COMPLETE QUALITY LINE . . .

POWELL VALVES FOR POWER PLANTS

FIG. 375—Bronze Gate Valve For 200 Pounds W.S.P

FIG. 1793—Iron Body Bronze Mounted Gate Valve For 125 Pounds W.P.

FIG. 19003—900-Pound Pressure Seal Gate Valve



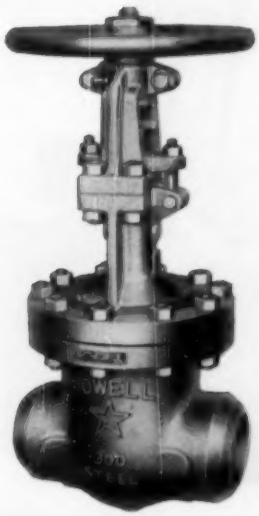


FIG. 3003—Steel Gate Valve For 300 Pounds W.S.P.

POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES

Just name the valve you need for your power plant—Powell can supply it. And you can be certain that every Powell Valve will give you *dependable* flow control.

Shown above are just a few Powell Valves for power plants. Investigate the *complete* line of quality valves that have a proven record of long life and dependable service.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our complete line, and help solve any flow control problem you may have. Write . . .

The Wm. Powell Company, Cincinnati 22, Ohio..... 109TH year

THE BIGGEST

*Announcing**

THE LQ600 VALVE

ANOTHER LUNKENHEIMER "FIRST"
. . . the revolutionary new bronze valve which has broken all existing performance records!

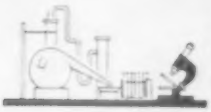
LUNKENHEIMER THANKS ALL OF THE LEADING COMPANIES WHO COOPERATED IN THE FOUR-YEAR LQ600 FIELD TESTING PROGRAM

The LQ600 Valve has been tested for four years in carefully chosen "problem installations" in American industry. *Despite the poor records of previous valves, there was not one single reported case of failure or leakage of an LQ600 Valve!* Here are a few typical records:

LUNKEN

THE ONE *Great*

BRONZE VALVE NEWS IN 50 YEARS!



This revolutionary brouze globe valve has set compietely new performance standards in the most severe service in industry!

LQ600 gives you so much *more* service per dollar that you can't afford to continue using bronze globe valves that require constant repair and replacement!

Valve users, cooperating in a four-year testing program, were unable to find *any* service tough enough to wear out an LQ600 — or cause it to leak, even in the most severe throttling installations! This new valve is an investment — one that pays cash dividends in maintenance savings year after year!

BRINALLOY* SEATS AND DISCS make these remarkable performance records possible. This exclusive new Lunkenheimer alloy is far more resistant to wear and corrosion than 500 Brinell Stainless Steel — even outwears case hardened Stainless Steel exceeding 1000 Brinell! There is no need for renewability. *No LQ600 Valve in four years service has required maintenance.*

OTHER FEATURES — a streamlined new exterior . . . the famous Stemalloy® Stem, which far outlasts any other stem material . . . the cool, easy-to-grip Non-Slip® patented handwheel . . . durable, high-strength bronze in body and bonnet . . . and true back-seating, permitting safe and easy repacking under pressure.

*Patented alloy. Trade Mark, The Lunkenheimer Co.

For more information, call your local Lunkenheimer Distributor or write The Lunkenheimer Company, Box 360, Cincinnati 14, Ohio.

TYPE OF SERVICE	LIFE OF OTHER VALVES	USER COMMENT
125 lb. base steaming	2 wks. to 2 mos.	Toughest service, previous valves leaked.
Water col. blowdown	2 mos.	Plug valves couldn't take it.
185 lb. steam blowdown	1 yr.	Plug valves failed every year.
125 lb. steam blowdown	"Short"	Previous valve leaked every run.
200 lb. steam—water col. blowdown	2 mos.	Previous valves failed by wiredrawing.
Throttling syrup 140°F.	"Short"	Previous valves cut.
150 lb. throttling 380°F.	6 mos.	Plug valves failed regularly.
100 lb. throttling	2 wks. to several mos.	Plug valves couldn't hold up.
130 lb. throttling	8 mos.	Composition seat valves unsatisfactory.
110 lb. throttling steam	3 wks. to 3 mos.	Three other kinds failed.
Scaled hot water line	"Short"	About all makes used—none held up.
125 lb. throttling steam	6 to 12 mos.	Plug valves failed by wiredrawing.
150 lb. steam—scale present	"Short"	Previous valves broke.
150 lb. throttling steam	4 to 5 mos.	Other makes failed by wiredrawing.

HEIMER®

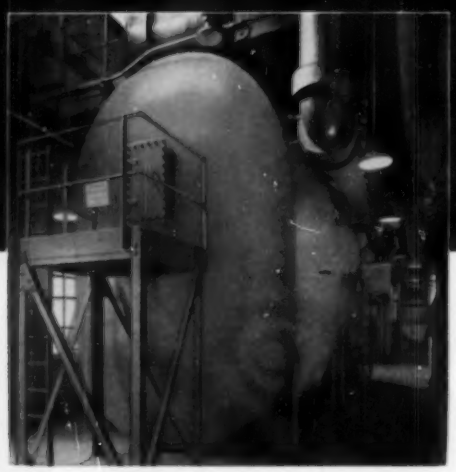
BRONZE • IRON
STEEL • PVC

NAME IN VALVES

L-455-A

problems in water-conditioning . . .

COMPLETE DEAERATION



Cochrane

Deaerating Efficiency

produces "ZERO OXYGEN!"

The guaranteed completeness and dependability of Cochrane physical deaeration is unsurpassed!

Cochrane pioneered in this field and today has the largest number of deaerator installations in the world. Cochrane's background in deaeration is your assurance that *guarantees will be met!*

Cochrane Corporation designs and manufactures complete lines of deaeration, precipitation, ion exchange and water conditioning equipment. This *complete* service provides single responsibility for engineering, fabrication and continued satisfaction. Consult Cochrane first . . .

For further information on Cochrane Deaerators, write for literature.

COCHRANE DEAERATOR IN A LARGE UTILITY

This giant Cochrane Deaerator, installed in one of the country's largest utilities, has been meeting guarantees for ten years. Special elliptical design was dictated by space limitations. With a capacity of 1,900,000 lbs. per hour, condensate is deaerated to zero (0.005 cc per liter or less) before being fed to high pressure boilers.

COCHRANE CORPORATION · WATER ENGINEERS SINCE 1863 · PHILADELPHIA

Cochrane
CORPORATION

Representatives in 30 principal cities in U.S.; Toronto, Canada; Paris, France; La Spezia, Italy; Mexico City, Mexico; Havana, Cuba; Caracas, Venezuela; San Juan, Puerto Rico; Honolulu, Hawaii.
Pottstown Metal Products Division—Custom built carbon steel and alloy products

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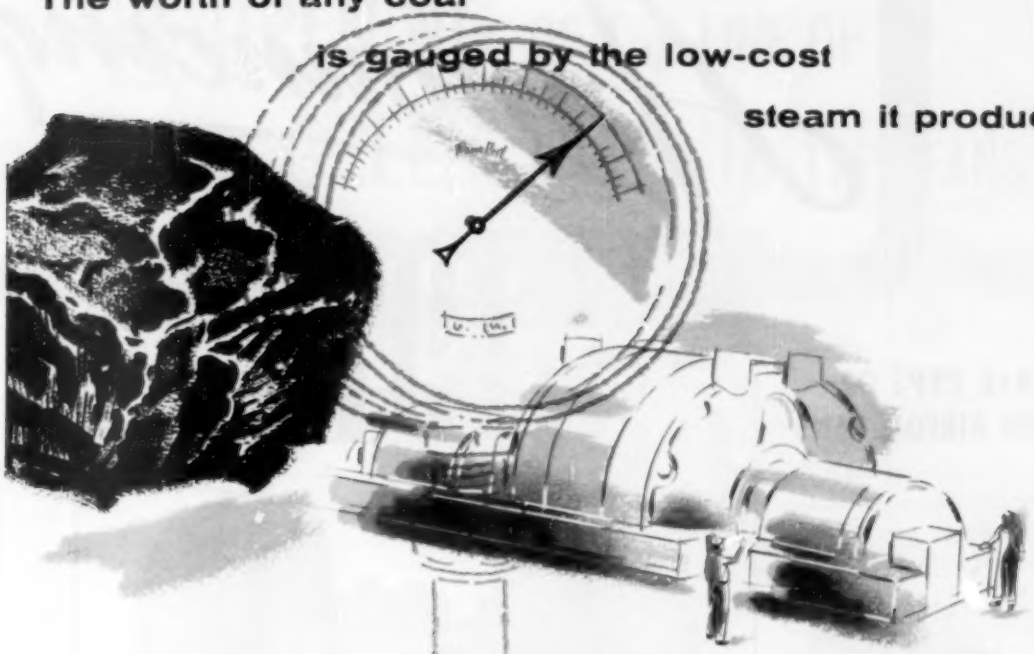
NEW YORK • PHILADELPHIA • CHICAGO

Demineralizers • Hot Process Softeners • Hot Zeolite Softeners • Dealkalizers • Reactors • Deaerators • Continuous Blowoff Systems • Condensate Return Systems • Specialties

The worth of any coal

is gauged by the low-cost

steam it produces!



OLD BEN COAL

Long famous for its rugged steaming and storage qualities, genuine Franklin County coal becomes an even greater performer through processing in Old Ben's precision preparation plants. Refined and sized to a rigid standard, each Old Ben industrial size is engineered for a specific job in the production of low-cost steam. Served by four major railways and accessible to rail-water transportation, the rich, centrally located Franklin County coalfield has the twin advantages of superlative inherent quality and low shipping costs. ...Consult an Old Ben engineer...and pave your way to lower operating costs!

wherever heat, light or power is needed

OLD BEN COAL CORPORATION

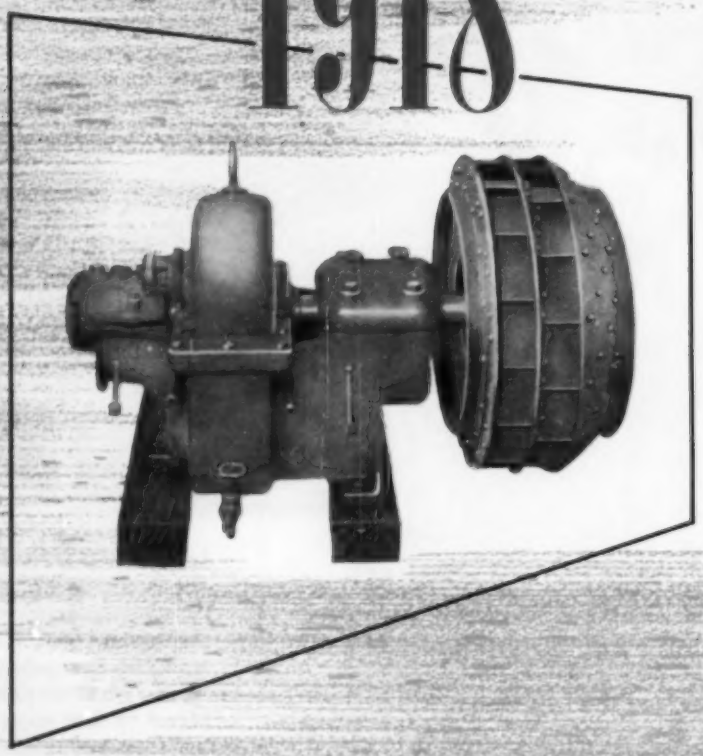
CHICAGO 4, ILLINOIS

Announcing 1918

1918 TYPE OF GREEN AIRFOIL FANS

Typical of the scores of AIRFOIL Type Fans we designed, manufactured, and shipped some 35 years ago. Some of these units are still in service.

These two drawings with dates in the World War I era show details of the Green AIRFOIL Type Fans as designed and manufactured by us in those days.



We use the word 're-opening' purposely for in 1918 at our factory in Beacon and for a few years thereafter we designed, manufactured and shipped many AIRFOIL Type Fans. *The AIRFOIL Type of Fan is not new.* But it has been modernized, refined and improved. Basically, the 1955 fans are not unlike the 1918 units. The blades then and the blades today simulate the design of the airplane wing. Then, as today, this type of blade produces considerably higher mechanical and static efficiencies than other types of blades.

The 1955 Line of Green AIRFOIL Type Draft Fan consists of six (6) different design variations which provide wide latitude in the choice of volume-pressure combination. Conservatively rated—as has always been a Green policy—these fans show exceptionally high static and mechanical operating efficiency.

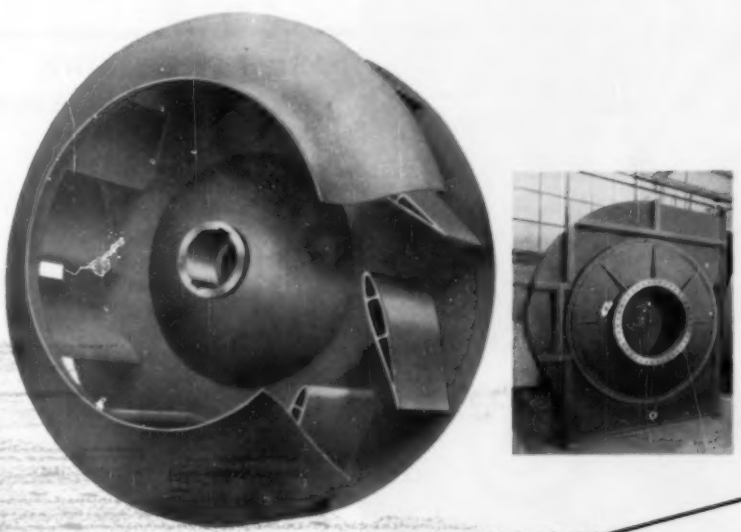
We are designating our line of AIRFOIL Fans as the CALEX Fans. They really deliver gales of air.

Complete details of the Green AIRFOIL Fans will be sent on request. Our engineers will be glad to discuss your fan requirements if you have any specific questions.

THE RE-OPENING OF THE LINE OF GREEN AIRFOIL TYPE FANS

1955 VERSIONS OF 1918 DESIGNS

1955

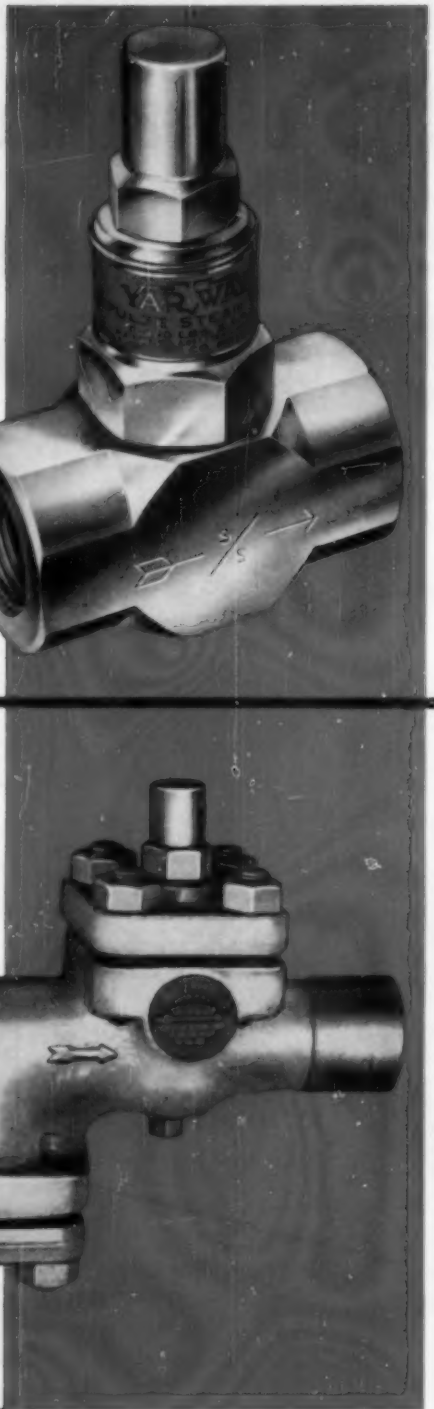


1955 VERSION OF AN AIRFOIL TYPE FAN

GREEN THE AIRFOIL TYPE FAN Galex FAN

GREEN
POWER AND PROCESS PLANT EQUIPMENT

FUEL ECONOMIZER COMPANY
BEACON 3, NEW YORK



which impulse for you?

STANDARD STEAM TRAP

The standard YARWAY Impulse Steam Trap serves all normal trapping requirements. Factory set to operate without adjustment at all pressures from 20 psi to 400 psi (Series 60) and 600 psi (Series 120). For pressures below 20 psi, merely remove split washer.

Numerous advantages like:

small size
quick heating
steady temperatures
stainless steel construction
one moving part
non-freezing
low cost

More than 900,000 used throughout industry.

Write for YARWAY Bulletin T-1740.

HIGH PRESSURE, INTEGRAL-STRAINER STEAM TRAP

YARWAY Integral Strainer High Pressure Impulse Steam Traps operate on some of the highest pressure steam lines in the country. Same operating principle as the standard YARWAY Impulse Trap. Strainer built into trap.

Ample capacity when system is being "warmed up"—yet will handle relatively small amounts of high temperature condensate without losing prime. Six sizes—½" to 2". Pressures to 1500 psi (flanged ends) or 2500 psi (welding ends).

Write for YARWAY Bulletin T-1740.

YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.

YARWAY

impulse steam traps

YARWAY Impulse Steam Traps and Fine Screen Strainers are stocked and sold by more than 250 convenient local distributors. Write for name of one nearest you.

PACIFIC®

The Ultimate Tribute to Quality...

150%

REPEAT ORDERS

from users of

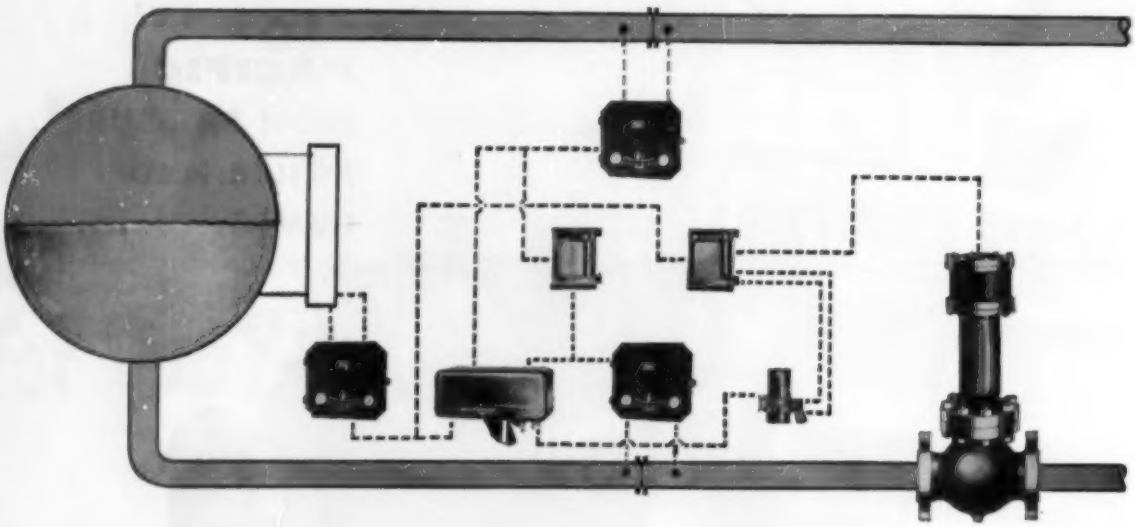
PACIFIC HIGH PRESSURE BOILER FEED PUMPS

PACIFIC PUMPS INC.

Write for **BULLETIN 122** *for details*

NEW! COPES offers a choice of

. . . WITH RECORDING INSTRUMENTS



From the oldest comes the newest in three-influence feed water control—Copes Type 3-L with Taylor instruments. A minimum of instruments are required due to simplicity. Miniature recorders are indicated above. Standard size recorders may also be used to supply as many as four records on one chart. Each component of the Type 3-L system is selected for its accuracy and high quality. Each installation is backed by nationwide service, whenever or wherever required, for its entire life.

Copes three-influence control may also be actuated mechanically or electrically

COPES

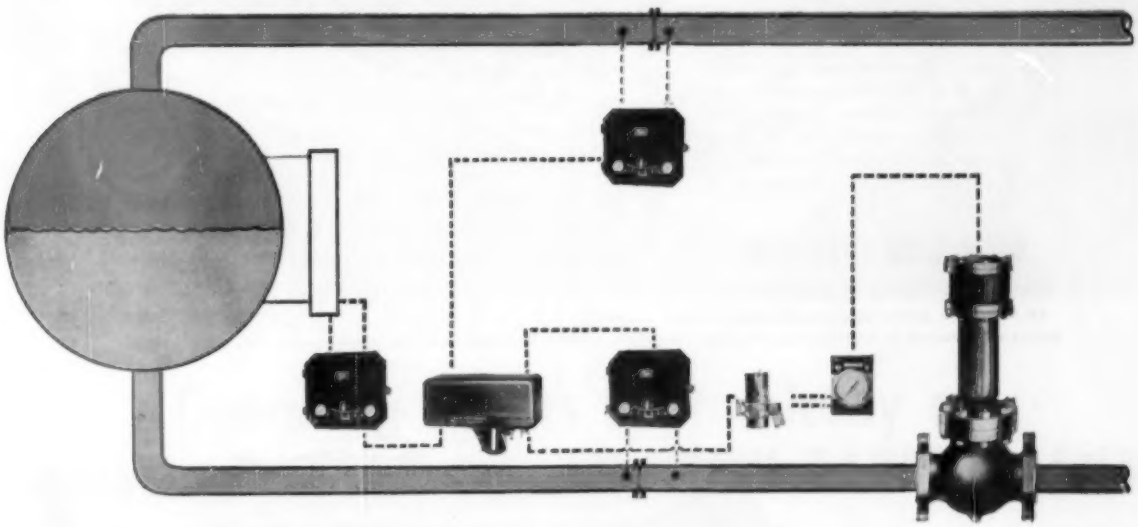
First to develop continuous

BOILER FEED

TYPE 3-L SYSTEM

3-influence controls

. . . **WITHOUT** **RECORDING INSTRUMENTS**



To further simplify a 3-L system, recorders may be omitted. The schematic shown above is the simplest instrument-type Copes three-influence feed water control system that is available. Ask for Bulletin 103-A which describes the combinations available in Type 3-L feed regulation.

COPES-VULCAN DIVISION

CONTINENTAL FOUNDRY & MACHINE COMPANY

ERIE 4, PENNSYLVANIA

boiler feeding under automatic control

WATER REGULATION

The USS Forrestal—

another example of how Walworth helps protect a 200 million dollar investment

Walworth products installed aboard the *USS Forrestal* include gate, globe, and lubricated plug valves and pipe fittings. They are used on high pressure air lines, fire mains, and most of the other piping systems throughout the ship.

Thousands of Walseal® Bronze Valves, Fittings, Flanges, and Unions comprise the major portion of the Walworth installations.

Walseal is a registered trade mark which identifies valves and fittings manufactured by the Walworth Company. Walseal products have *factory-inserted rings* of silver brazing alloy in threadless ports. Walseal joints can be made only with Walseal valves and fittings.

WALWORTH

valves . . . pipe fittings . . . pipe wrenches

60 East 42nd Street, New York 17, N. Y.

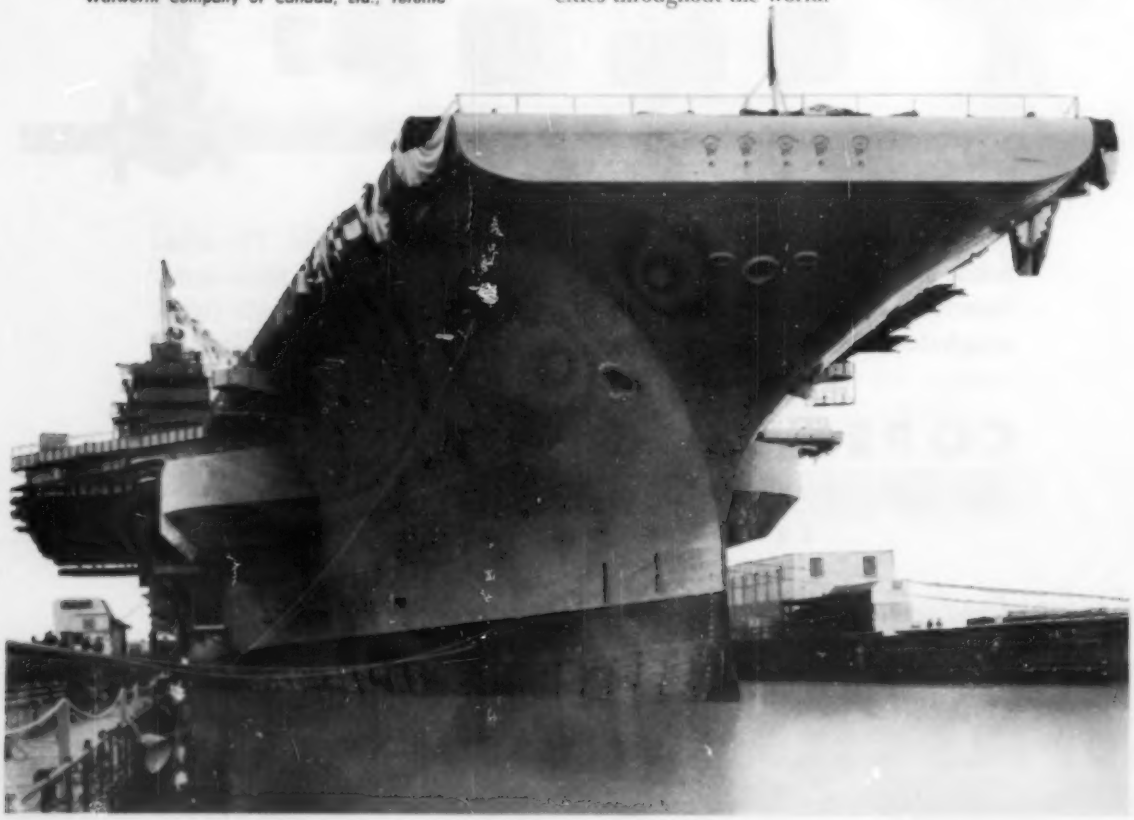
Walworth Company of Canada, Ltd., Toronto

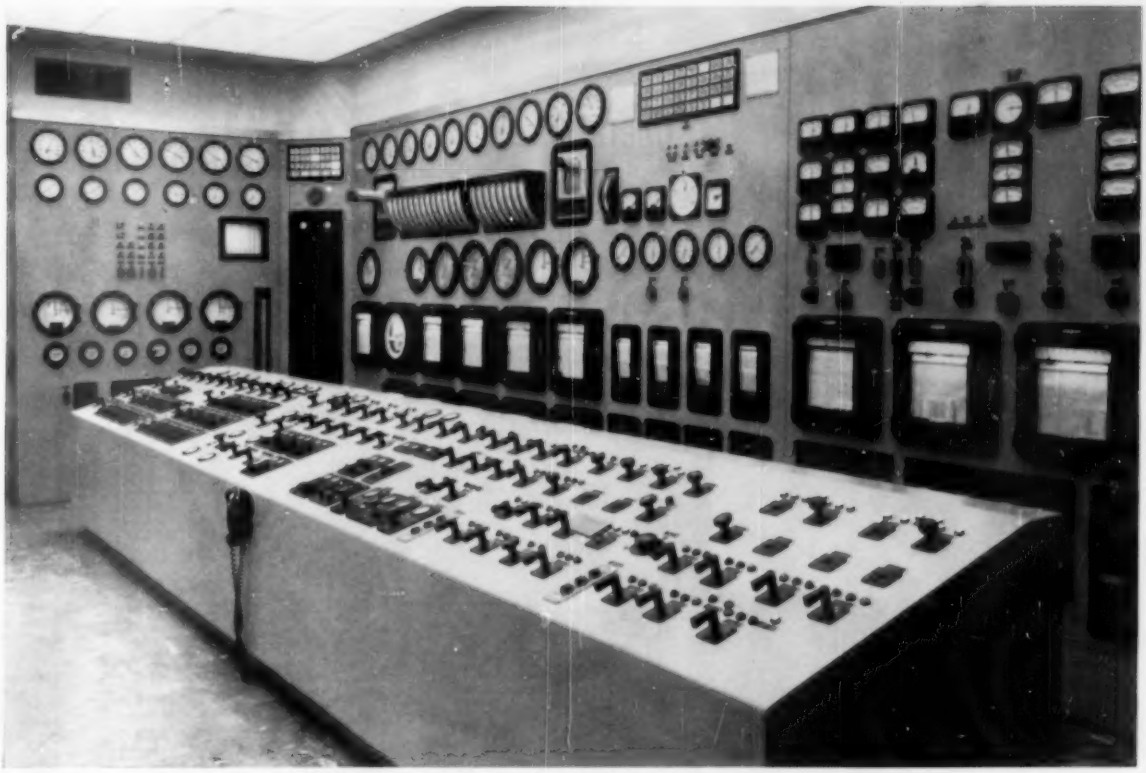
Keel laying to launching—Walworth was there.

Walworth engineers worked with designers, metallurgists and builders of the mighty flat-top right from the blueprint stage. Their efforts assured the builder – Newport News Shipbuilding and Dry Dock Company – that *every* Walworth Valve and Fitting installed would meet *every* specification right down to the finest detail.

The *Forrestal* – like the *USS Nautilus*, the first nuclear-powered submarine – is another striking example of where Walworth engineering and products were called upon to protect a multimillion dollar investment.

Walworth, backed by 113 years of practical valve experience, is skilled in every type of installation. Whatever the industry, if your problem concerns valves or fittings, it will pay you to call on Walworth! Distributors in principal cities throughout the world.





Centralized controls for station service switching, two 125,000 kw turbines, generators and boilers are in this room. Republic sub-panels on the bench board provide for either automatic or manual control of the boilers.

Operating Boilers Electronically at Alabama Power Company's NEW BARRY PLANT

At the new Barry Steam Plant near Mobile, Alabama, two 900,000 lbs. per hour pulverized coal fired boilers operating at 1875 psi and 1000°F. are controlled by a Republic Electronic Master Combustion Control System.

Electronic impulses control pneumatically operated fuel, draft, and feedwater regulators on the boilers. Master control signals are transmitted practically instantaneously, permitting fast control response and close boiler control.

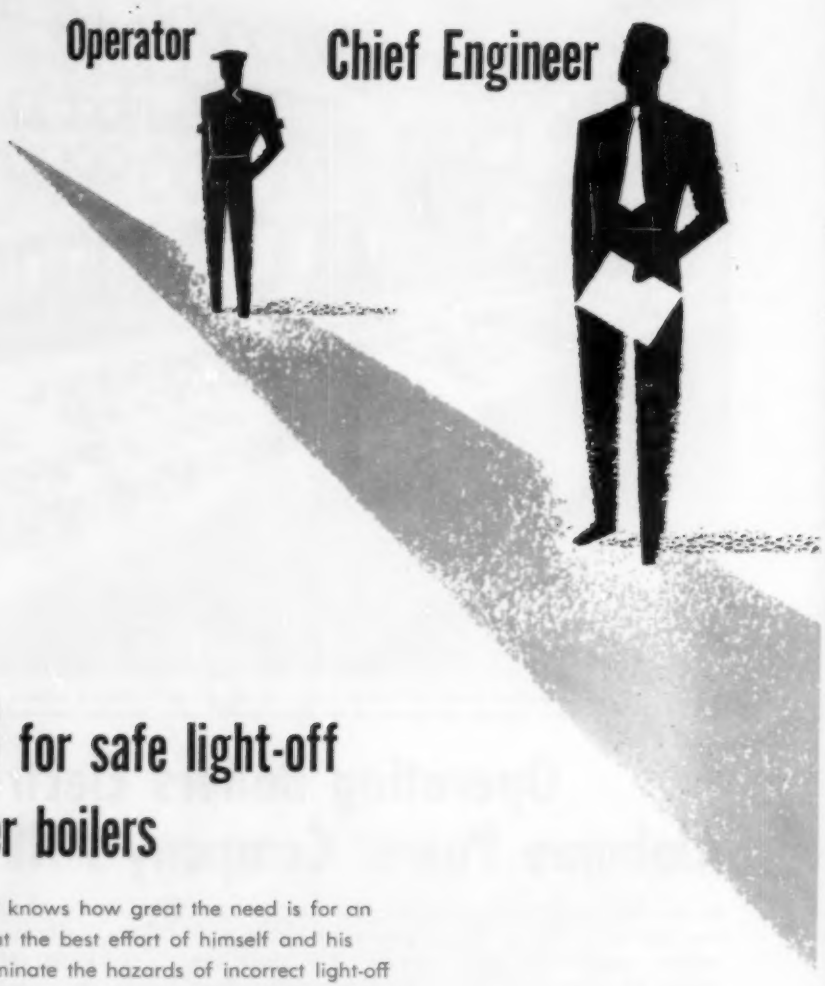
To ensure that both final firing rate and air flow will rapidly and accurately follow changes in steam load, the control system normally follows a dual element master control. This master controls the boiler auxiliaries from a rapid and proportional steam flow function together with a stabilized steam pressure function. Such a system combines the features of derivative control with automatic correction for fuel variation in such a manner that the effects of load swings are minimized almost to the vanishing point. Other control problems such as feedwater control and steam temperature control are simplified by the coordination of boiler auxiliary functions due to this system of combustion control.

Boiler feedwater is controlled automatically by a Republic three-element feedwater control. To prevent heat damage to feedwater pumps during low flows, a Republic pump by-pass system has been installed. It automatically maintains a minimum flow of 125 gpm through each pump (two pumps per boiler) returning by-passed water to the deaerating heater storage tank.

Final efficiency tests recently completed at the Barry plant indicate the expected plant heat rate has been fully realized. There are Republic Automatic Combustion Control Systems — electronic or pneumatic — for all sizes and types of boilers, all methods of fuel firing and for any arrangement of draft equipment. For full details, write today.

REPUBLIC FLOW METERS CO.

2240 Diversey Parkway, Chicago 47, Illinois



You need ALL 3 for safe light-off and firing of power boilers

Any able and experienced "Chief" knows how great the need is for an assistant like Fireye. He knows that the best effort of himself and his operating men isn't enough to eliminate the hazards of incorrect light-off and flame failure – hazards which insurance surveys show cause 85% of furnace explosions.

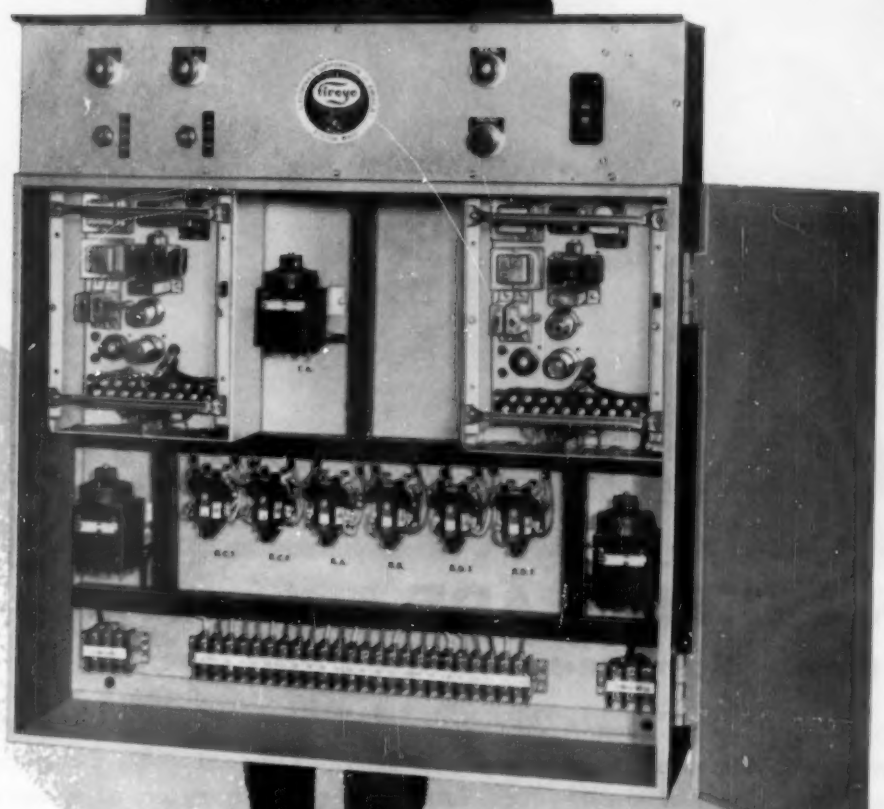
Fireye gives you protection assurance that's obtainable only with a factory-integrated system of timers, interlocks, and shutoff valves. It controls every stage of burner operation. And, if a flame fails, Fireye shuts off fuel in 2 to 4 seconds . . . will not allow re-ignition before the combustion chamber is completely cleared of explosive gases.

The system may be installed on any multiple burner boiler. Installation supervision by qualified Fireye engineers is part of our national service, when desired.

Get important new manual . . . "How to Burn Fuel Safely", an authoritative easy-to-understand manual which tells how to spot operating hazards and safeguard against them. Use the coupon to get it. Or, ask your local Fireye representative for a copy.

now fireye

the "3rd man" in your boiler room



New INTERLOCK System automatically . . .

PREVENTS hurrying or bypassing steps essential to safe boiler operation.

PREVENTS light-off until combustion chamber and passages are purged free of combustibles.

PREVENTS supplying main fuel until pilot is proved at a point satisfactory for light-off of main fuel.

SHUTS OFF FUEL if main flame is not stable within safe trial-for-ignition period.

SHUTS OFF FUEL and sounds alarm if flame goes out during firing period.

E C A fireye

First and Foremost in Controls for Safe Fuel Burning

Other ECA Divisions: Photoswitch Division Fireye Division • Marine Division • Business Machines Division • Photoconductor-Transistor Division • Military Division

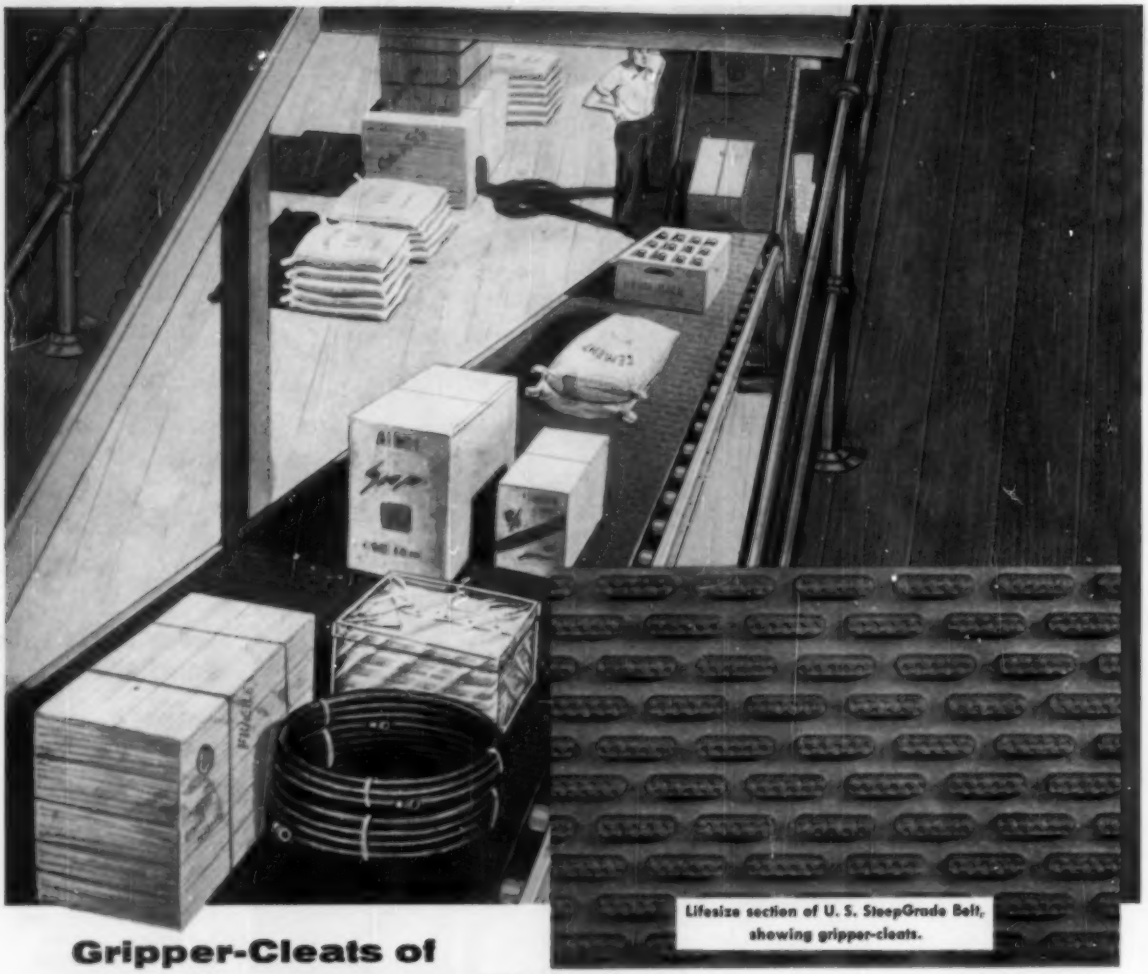
COMBUSTION CONTROL DIVISION
ELECTRONICS CORPORATION OF AMERICA
Dept. C25-7, 718 Beacon St., Boston 15, Mass.

Please send me your new manual — "How to Burn Fuel Safely".

NAME AND TITLE _____

COMPANY _____

STREET _____ CITY _____



Lifesize section of U. S. SteepGrade Belt, showing gripper-cleats.

Gripper-Cleats of U. S. STEEPGRADE Provide Non-Slip Package Control on Steep Inclines and Declines

The new, *exclusive* gripper-cleats of the U. S. SteepGrade Belt give positive non-slip control of many materials on ascents or descents as steep as 45 degrees. This feature also saves floor area and belt footage, because the steeper the incline the less floor space occupied. The U. S. SteepGrade Belt is perfect for small buildings.

Note the gripper-cleats in the close-up photo of the belt section. These cleats are *not* attached or cut in; they are *molded*—a true and integral part of the belt. That's why they resist being torn off by heavy cases. The special surface design allows the belt to *clean* itself as it flexes over the pulleys.

This remarkable new belt is obtainable at any of the 27 "U. S." District Sales Offices or by writing address below.

"U. S." Research perfects it . . . "U. S." Production builds it . . . U. S. Industry depends on it.

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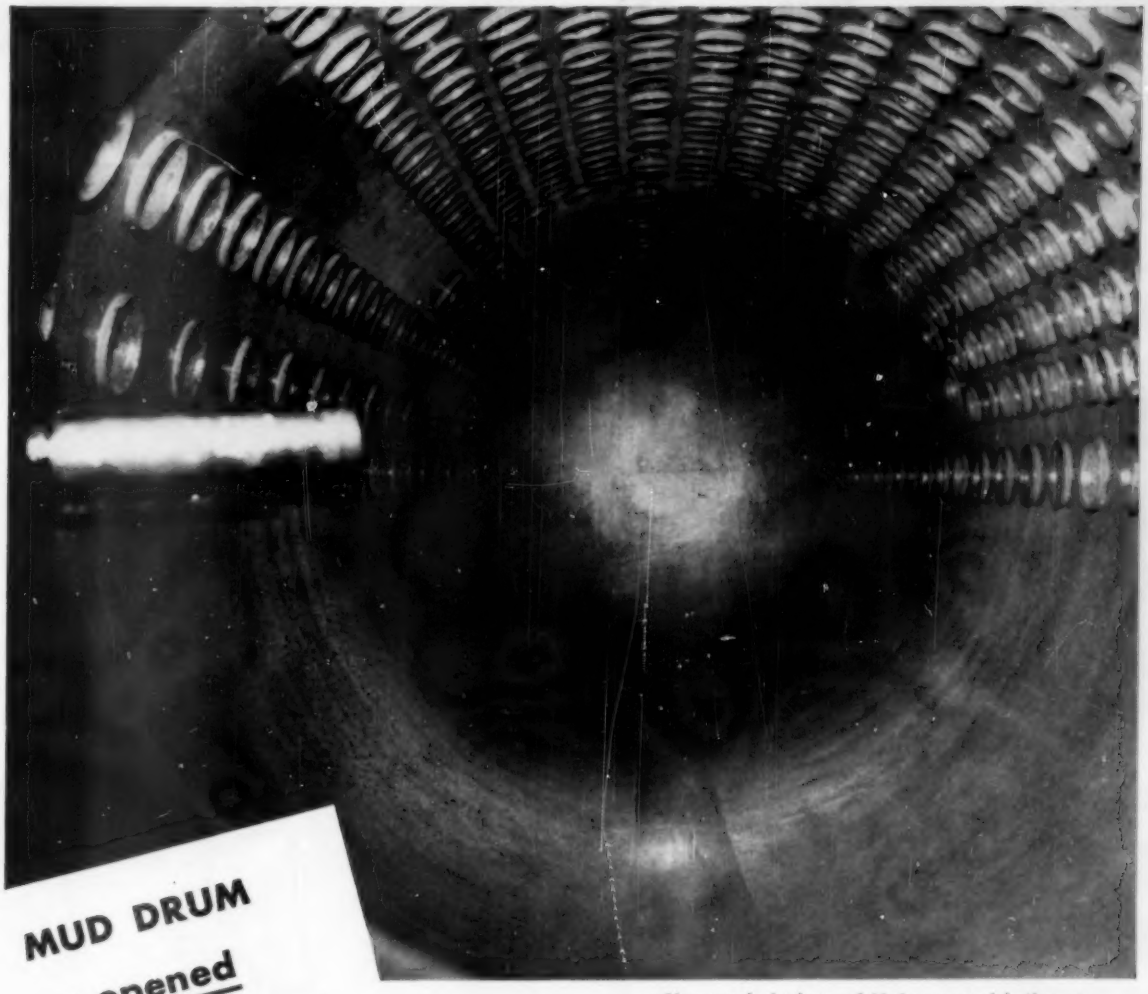
MECHANICAL GOODS DIVISION · ROCKEFELLER CENTER, NEW YORK 20, N. Y.

Hose • Belting • Expansion Joints • Rubber-to-metal Products • Oil Field Specialties • Plastic Pipe and Fittings • Grinding Wheels • Packings • Tapes Molded and Extruded Rubber and Plastic Products • Protective Linings and Coatings • Conductive Rubber • Adhesives • Roll Coverings • Mats and Matting



MUD DRUM
as opened
after one year
on line
with
THE *Nalco* SYSTEM

Unretouched photo of Nalco treated boiler at Georgia Institute of Technology, Atlanta, Georgia

● Calling this a mud drum serves only to identify its location . . . it is perfectly clean after a full year on line. The unretouched photo was taken immediately after the drum was opened. No wash-out was necessary. Not only is the drum free of scale and corrosion . . . Nalco sludge conditioning operated so effectively that even under the static, off-line draining condition, no sludge deposited in tubes or drums.

The Nalco System can get results like these, economically, in *your* plant—regardless of boiler size or pressure. Write or phone Nalco today for action on a complete water treatment program.

NATIONAL ALUMINATE CORPORATION
Telephone: POrtsmouth 7-7240
6234 West 66th Place • Chicago 38, Illinois
In Canada: Alchem Limited, Burlington, Ontario

THE *Nalco*® SYSTEM . . . Serving Industry through Practical Applied Science

Bailey Recorder for receiving pneumatic and electric signals.

Measured Variables
% combustibles
combustion
conductivity
density
differential
draft
flow
liquid level
% oxygen
pH
position
pressure
ratio
smoke density
specific gravity
speed
temperature
vacuum

Pick any four, plug in, and record

Here is a receiver recorder, custom-built *by you* to meet your needs, no matter how changeable, how complex. On a single chart you can record any four measured variables—and interchangeable receivers permit new combinations almost at will.

Individual plug-in pneumatic or electronic receivers—and corresponding integrators—are interchangeable in the four identical frame slots. You can select any combination; even including two receivers and their two integrators.

Think what this can mean to you! Parts inventories are minimized; re-use of components keeps instrumentation costs economically low when cycle changes are frequent—and you can even tie in with your existing transmitters.

Ask for Product Specification E12-5.

PBA-1

ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER

- Pre-calibrated plug-in receiver units
- Up to four pneumatic or electronic receivers —or two receivers and two integrators
- Any four variables on one chart—easily read and interpreted
- A full year's ink supply at one loading
- Faster ordering—from stock
- Minimum inventory of parts
- Minimum instrument investment for process cycle expansion or alteration

BAILEY METER COMPANY

1025 IVANHOE ROAD

CLEVELAND 10, OHIO

Controls for Power and Process

BAILEY METER

Controls for

TEMPERATURE
PRESSURE
GAS ANALYSIS
FLOW LEVEL
RATIO DENSITY

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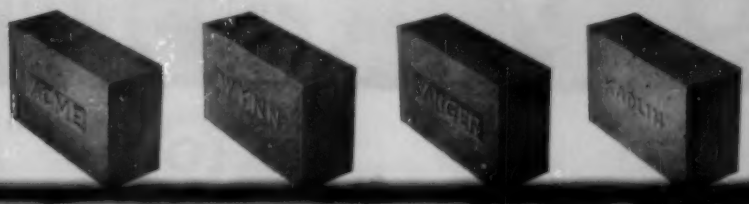

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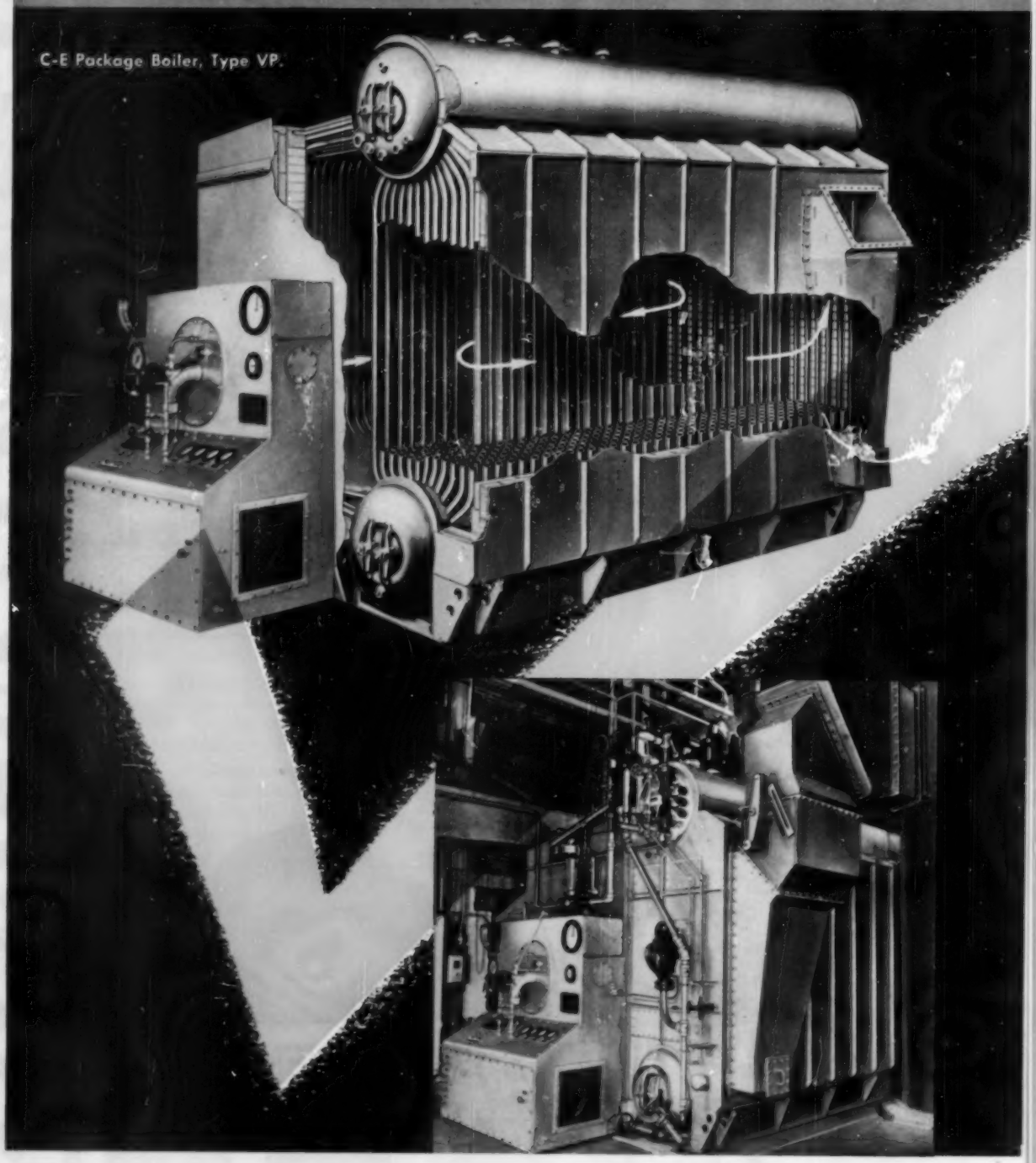

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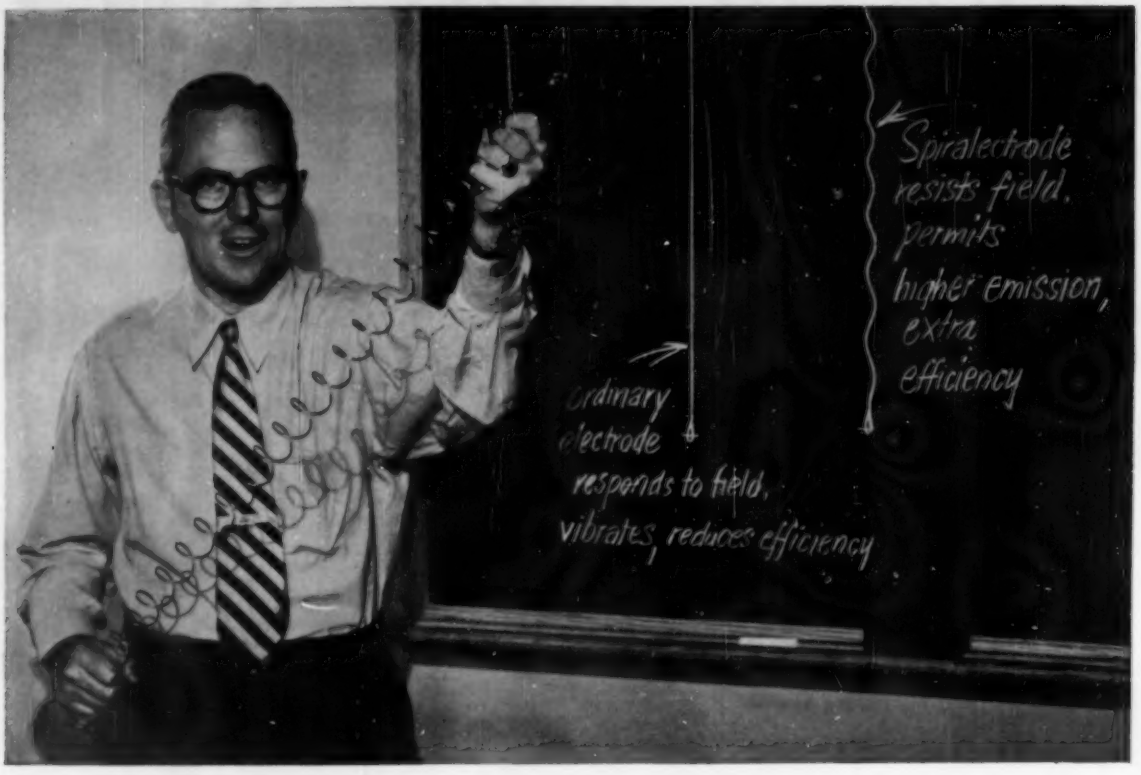
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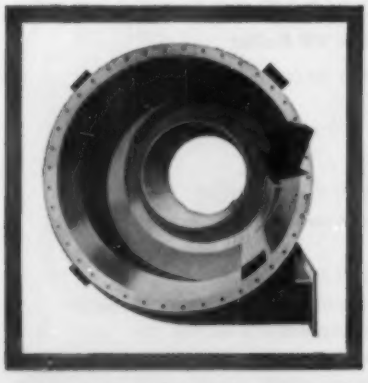

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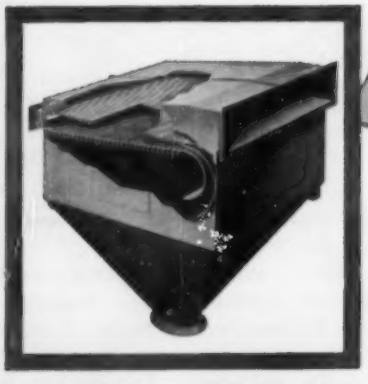

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Editorials

A Moving Target

The nuclear energy power plant as an economically competitive form of producing electric energy admittedly has a number of years ahead of it before it reaches this laudable goal. The recently concluded Edison Electric Institute meeting in Los Angeles in mid-June gave further evidence that the goal is not a fixed one.

The Texas Power & Light Co. was presented with the Charles A. Coffin Award for 1954 for its "extraordinary enterprise and resourcefulness" in opening up the uses of lignite as a low-cost fuel. This utility entered into an agreement with the U. S. Bureau of Mines to determine how Texas lignite could be used more effectively as a fuel. As reported earlier (COMBUSTION, March 1954, p. 38) a new process of dehydrating and charring crushed lignite was developed that made the lignite an improved heat source and created by-products that hold out high promise on their own.

At this same meeting R. G. Rincliffe, president, Philadelphia Electrid Co., gave, in effect, a progress report of the privately operated power generation industry. It was a practical presentation tracing the achievements over the years and discussing the expected role for the supercritical pressure power stations now coming into reality. The paper did not minimize the problems facing the industry but it did hold out the conviction that the solutions would come from a continuance of the industry's traditional willingness to experiment and to finance the development of these experiments toward improving the art of lower cost power production.

Both of these incidents are expressions of a pattern. It is readily apparent that today's power generating industry is not of a mind to sit back and let things come to pass. This industry is not only in the forefront in advancing the development of nuclear energy for the power field but they are not passing up a single bet in methods and means of squeezing more out of the conventional fuels or preparing the hitherto marginal fuels to fit them for power generation purposes. It is a stimulating experience to see so large and widespread an industry display such an aggressive, exploratory attitude in its desire to hold its present respected position into the future. We feel it provides the right climate for growth.

Cleaning and Water Conditioning for Initial Operation of High-Pressure Boilers*

By J. D. RISTROPH†

Virginia Electric and Power Company

The experience of Virginia Electric and Power Company in establishing the chemical cleaning and water treatment procedures for preliminary operation of high pressure controlled-circulation boilers is described. Included are observations and recommendations for cleaning of the condensate-feedwater cycle, the boiler, and the steam lines. Initial and sustaining water treatment is covered briefly.

THE initial operation of a new unit is normally preceded by considerable preparatory work that can possibly be classified under the loose term of preliminary operation. Into this category, in chronological order, can fall the initial cleaning of the feedwater cycle, the chemical cleaning of the boiler, initial external and internal feedwater treatment, and the blowing out of the steam lines.

It is realized that each installation presents its own peculiar problems, with field conditions necessitating and governing the type of treatment and method of application of such treatment. However, the basic principles remain valid and unchanged in the great majority of cases. We shall not attempt to outline or validate these basic principles that are generally accepted by the industry, but rather shall present the present approach and application of these elementals by the Virginia Electric and Power Company on the recent initial operation of our latest controlled-circulation units.

This unit consists of a controlled-circulation boiler rated at 750,000 lb per hour, steam conditions, 1500 psig and 1000 F at the superheater outlet, with reheat to 1000 F. The turbine is rated at 100,000 kw, with five stages of extraction. The feedwater is heated with five stage heaters, with deaeration at the condenser and third stage of heating, Fig. 1.

Establishing Procedure

Past practice of this company with respect to initial cleaning of the feedwater cycle had been to merely flush out the system as well as possible. The Portsmouth Station is located on very sandy soil. Experience on No. 1 Unit showed that considerable sand pickup had been experienced during construction work, resulting in high silica concentrations in the boiler during initial operation. With this unfavorable condition to contend with, and with the thought of incorporating degreasing of the system into the preliminary cleaning, a radical change of procedure was initiated.

The feedwater lines were thoroughly flushed. A temporary recirculation system was established by running piping from the inlet of the economizer to the distilled water tank. The normal makeup line, from the distilled water tank to the condenser, was rerouted at the condenser to enter into the lower section of the condenser hotwell. Strainers were installed at all pump suctions, with pressure gages installed upstream and downstream of the strainer. Provisions were made to supply 200 psi to the deaerating heater.

Then the system was filled with demineralized water containing 100 ppm trisodium phosphate and caustic soda to elevate the pH to 10.5–11.0. Recirculation was attained by running the condensate pump, condensate booster pump, and the boiler feed pump. Steam was admitted to the deaerating heater and a temperature of 185 F was maintained at this point. The recirculation was discontinued after eight hours.

The strainers were cleaned during the night and considerable debris was removed. This was especially true of the strainers on the boiler feed pump. The recirculation was then carried on again for eight hours under similar conditions.

After this the system was drained. On inspection the water was found turbid, with considerable suspended iron oxide. The distilled water tank and the hotwell were flushed out, as well as other points of possible collection of heavy particles. A considerable amount of welding beads were found in the hotwell. The system was then refilled with condensate.

The combined effects of the mass velocity flushing, the chemical treatment, and the temperatures attained were evidenced in the latter stages of preliminary operation in low turbidities in the boiler, and extremely low silica content of the boiler salines. During the generation of steam for blowing out of steam lines, the maximum silica encountered was 3.0 ppm, with an average value of 1.7 ppm. Similar values for No. 1 Unit, on which the feedwater lines had been merely flushed out, were as high as 15 ppm.

Some consideration is being given to increasing the temperatures and mass velocities of such flushings in the future on new feedwater cycles.

Complete chemical cleaning of these systems would probably be the ultimate for optimum results. This has been satisfactorily accomplished in several instances by another public utility and is to be done in the near future by several utilities. However, it is felt that consideration should be given to design of the system if acid cleaning is to be used. In this case, provisions would

* Presented at Spring Conference of Southeastern Electric Exchange, New Orleans, La., April 7–8, 1955.

† Chief Chemist

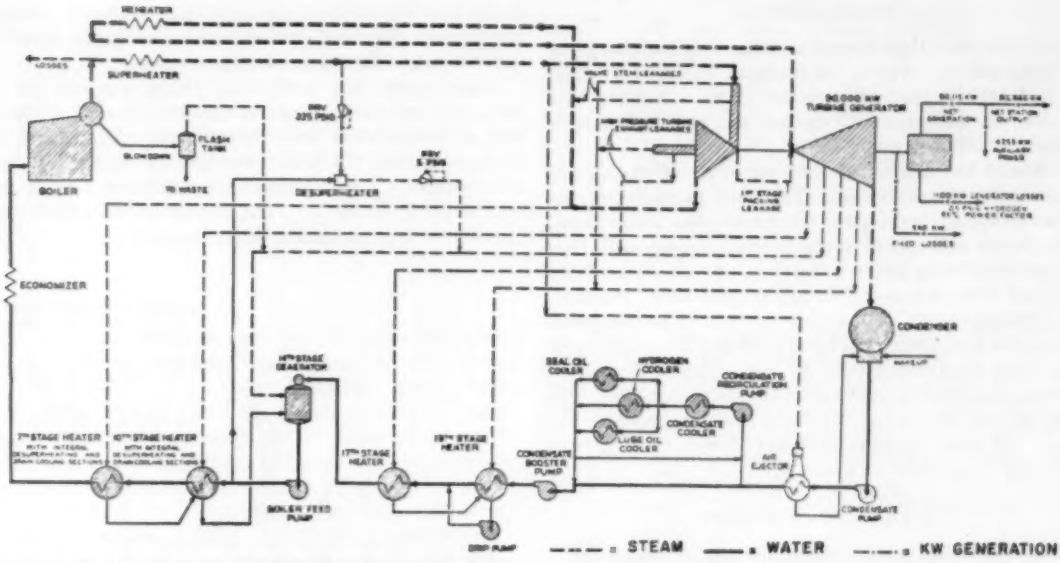

Fig. 1—Feedwater cycle of Virginia Electric and Power Company's latest controlled-circulation boiler which underwent the water treatment procedure described in the article. Note the five stages of water heating.

necessarily have to be made for drainage of all low points or points of entrapment in the system, and for proper venting of the system.

The controlled-circulation boiler is particularly adapted to chemical cleaning, primarily because of the controlled-circulation feature, which greatly facilitates control of treating conditions, especially those of temperature and chemical concentration. The procedures discussed in this paper relate to this type of boiler, but may also be applied in general principle to natural circulation units.

There is some present-day disagreement relative to the need of pre-boil conditioning of the boiler prior to initial operation because modern boilers are relatively grease-free due to present construction and fabrication processes. This disagreement is more intense relative to the need of initial mill-scaling prior to initial operation. There are proponents of no chemical cleaning, chemical cleaning after a relatively short period of operation, and chemical cleaning prior to initial operation. The Virginia Electric and Power Company places itself in this latter group, both for chemical cleaning and initial pre-boil operations.

While details and chronological log of the boil-out and acid-cleaning procedures are shown in the Appendix, the basic procedures that are used are discussed.

Included in the preparatory work was the back-flushing of all tubes in the boiler with water, including all horizontal and platen wall tubes. Past experiences of our and other companies indicate that this is a desirable feature.

Techniques Employed

A special assembly was fabricated to facilitate the rapid filling and discharge of boiler tubes. This assembly was composed of a piece of steel tubing, bent so it could be inserted through a hand-hole and fitted up to a boiler tube inlet end opening. A tapered rubber plug was used to insure a tight fit in the mouth of the boiler tube. The other end of the $^1/_2$-in. tubing was inserted in the outlet of a tee. One of the run ends of the tee was connected to a water supply and provided with a quick-opening valve and pressure gage. The other run end of the tee, also provided with a quick-opening valve, was piped to a strainer for collecting the debris flushed from the boiler tube, Fig. 2.

The technique adopted was to fit the assembly tightly against the boiler tube inlet end, open the quick-opening valve on the water supply with the outlet valve closed until the tube, or bifurcated tube, was filled. The supply valve was then closed and the drain valve immediately opened. A log of each tube was kept to indicate the pressure required to fill the tube, the length of time required, the color of the back-flush water, the number of flushes required to clear a tube, and the amount and description of the debris collected.

The boilout was begun after all incidental preparations for this and the following acid cleaning was completed. The superheater was filled with demineralized water. The boiler was filled to operating level with city water and the necessary chemicals added in the following proportions:

Chemical	Per 1000 units
Activated sodium sulfite	0.8 lb
Soda ash	2.0 lb
Sodium hydroxide	2.0 lb
Trisodium phosphate	4.0 lb
Dowell detergent	0.6 gal

The circulating pumps were run to uniformly disperse the chemicals. The boiler was slowly fired to 50 psig and maintained at this pressure for 24 hr. The chemical concentrations and operational data were logged. Chemical levels were maintained, Table I. At the end of the 24-hr period of 50-psi pressure, the boiler was blown down 20 in. in drum level by alternate use of the blowdown valves. The boiler was refilled and the process repeated until a turbidity of 14 ppm was attained.

Chemical Cleaning

The boiler was then cooled and the original charge of chemicals added. The boiler pressure was raised to 200 psig and held at that pressure for 12 hr. Holding this pressure, the blowdown procedure was repeated until a turbidity of 20 ppm was reached.

It should be mentioned that no evidence of oil was noted during the procedure. This may partially be due to the method of cleaning the condensate-feedwater cycle.

The boiler was cooled in the normal manner with fans and one circulating pump in service. As all preparatory work had been completed, in accordance with "Preparatory Arrangements" shown on p. 42. The temperatures of the metal were the basic criteria. These temperatures were ascertained both by use of pyrocon contact thermometers and by use of installed thermocouples. The boiler was drained when the drum skin temperature was 190 F. All other temperatures were lower, ranging from 160 to 180 F as shown in Table II.

TABLE I—LOG OF BOIL-OUT

Time	Pressure	SO_3	PO_4	SiO_2	Turb.	Caustic Alk.
12:30 A	0	354	..	..	..	..
8:30 A	0	67	..	..	..	..
12:00 N	50	90	..	..	..	..
2:00 P	55	100	550	32.5	72	1106
6:00 P	58	183	400	30.0	46	1172
10:00 P	45	109	355	28.4	51	932
12:00 MN	52	104	..	..	..	..
2:00 A	53	109	325	22.2	67	786
4:00 A	48	104	330	23.9	55	..
6:00 A	50	109	300	23.7	67	..
10:00 A	53	105	283	22.6	46	653
12:00 N	54	97	..	..	..	626
2:15 P*	52	117	240	20.0	72	573
3:15 P*	45	93	200	14.0	42	493
4:15 P*	53	68	160	11.0	37	400
5:15 P*	54	56	125	9.0	46	306
6:15 P*	53	51	100	8.0	42	293
7:15 P*	53	66	88	7.5	37	213
8:45 P*	52	60	55	7.2	11	173
9:45 P*	50	56	50	6.5	12	160
		SECOND PHASE				
1:20 A	0	387	1216	5.8	90	2091
5:50 A	200	520	..	..	..	..
8:00 A	215	568	845	5.9	55	1878
12:00 N	242	568	845	6.4	46	1958
4:00 P	215	520	728	8.7	22	1758
6:00 P	215	472	664	8.7	20	1652
8:00 P	400	456	729	10.1	21	1678
12:00 MN	405	472	680	13.7	46	1812
4:00 A	405	460	758	13.6	67	1971
6:00 A	400	474	700	10.9	42	1971
6:25 A*	400	446	675	10.1	55	2025
7:20 A*	400	400	625	11.7	27	1732
8:22 A*	400	340	510	14.9	20	1518

* Blowdown and refill.

On initial chemical cleanings, the use of 6 per cent inhibited hydrochloric acid is normally used. It is also normal practice to add approximately 0.5 per cent ammonium bifluoride as an intensifier, or catalyst. This has been found to be very beneficial in promoting the removal of iron oxides. It has been found expedient and time-saving to have a dependable source of supply of hot water of proper temperature, or adequate means of heating the diluting water. This is also especially true of the need for provision of a permanent piping layout of adequate size to quickly fill and drain the boiler. This latter item is not only time-saving, but also promotes safety, and insures a more satisfactory cleaning, in that faster draining time lessens the possibility of redeposition of suspended material removed in the cleaning process.

The boiler was filled to desired level, ascertained by a temporary gage glass installed for this purpose, with acidic solvent at a temperature of 160–175 F. Time, temperatures and chemical concentrations were logged. Upon completion of the fill, a main boiler circulating pump was placed in operation for 10 min to insure uniformity of temperatures and concentrations. Temperatures and chemical concentrations of acidic strength, ferric iron and total iron were determined.

Once hourly, the circulating pump was run for five min, and the same values of concentration of chemicals and of temperature were determined. At the end of a six-hour period, the boiler was drained under a nitrogen atmosphere. The terminal temperatures ranged from 145 to 155 F, Table II. The normal draining time under pressure is approximately thirty minutes.

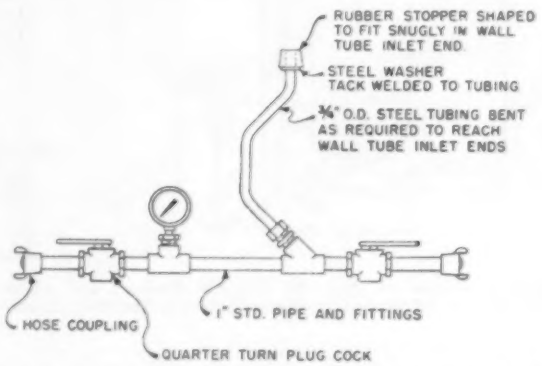
RUBBER STOPPER SHAPED TO FIT SNUGLY IN WALL TUBE INLET END
STEEL WASHER TACK WELDED TO TUBING
¾" O.D. STEEL TUBING BENT AS REQUIRED TO REACH WALL TUBE INLET ENDS
HOSE COUPLING
1" STD. PIPE AND FITTINGS
QUARTER TURN PLUG COCK

Fig. 2—Special assembly above was devised to facilitate filling and discharge of boiler tubes

The use of nitrogen, supplied from a main header to a connection on the top of the boiler drum to maintain a minin um of 5 psig, has been found to almost completely eliminate the "after-rust" or formation of iron oxide in addition to expediting draining time. The boiler remains under a nitrogen atmosphere from the beginning of the acid drain period until after the last rinse of the unit, or in other words, during all periods except the soaking period.

During the draining period, a composite sample of the spent acid was obtained for complete analysis.

The boiler was filled with city water for the first rinse. The circulators were operated for 15 min. The pumps were shut down and the boiler drained under nitrogen pressure. The pH of the drain effluent was 2.0. The process was repeated; at this time the pH had risen to 6.4. It is our belief that unless rinsing is carried out until the pH of the rinse waters is above 5.0 that there will be excessive formation and deposition of gelatinous iron hydroxide when the post-boil chemicals are added.

Post-Boiling

After completion of the required rinses, the boiler was filled with the post-boil solution of 1 per cent soda ash in demineralized water. Also added were 15 lb of TSP and sufficient sodium sulfite to give a sulfite residual.

The use of soda ash, in our experience and that of numerous others, gives as good or better protection against "after-rust" as any other post-boil solution. Comparative values have been reported by Cardwell (1).[1]

The boiler was slowly fired with light oil to a pressure of 400 psig, venting the nitrogen to atmosphere when 25

[1] Numbers in parentheses refer to Bibliography at the end of the article.

TABLE II—LOG OF CHEMICAL CLEANING

Time	HCl, %	Solvent Temp, F	Drum Temp, F: North	Drum Temp, F: South	Drum Temp, F: Skin	Tube Temp, F: North	Tube Temp, F: South	Lower Drums, F: West	Lower Drums, F: East
6:10 P	...	170	175	175	183	180	180	177	177
8:27 P	Boiler full of acidic solvent								
8:30 P	10 min recirculation								
8:45 P	7.0	...	155	155	160	155	155	150	150
9:30 P	5 min recirculation								
9:45 P	7.6	...	155	155	160	155	160	150	150
10:30 P	5 min recirculation								
10:45 P	7.2	...	150	150	160	160	160	150	150
11:30 P	5 min recirculation								
11:45 P	7.1	...	150	150	150	150	150	150	150
12:30 A	5 min recirculation								
12:45 A	7.0	...	150	150	155	160	160	150	150
1:30 A	5 min recirculation								
1:45 A	6.7	...	145	145	150	155	155	145	145
2:30 A	Began draining under nitrogen pressure								

psi was reached. This pressure of 400 psig was maintained for 24 hr. A log of chemical concentrations was maintained, Table III. It has been indicated that a much better job of "after-rust" prevention and metal preparation is achieved at conditions of elevated pressure and prolonged periods of time, rather than that found at lower pressures for shorter intervals.

At the end of the 24-hr period, the fires were shut down and the boiler cooled to 185 F, using the fans and one circulator. When the drum pressure reached 10 psig, nitrogen was reintroduced to maintain 5–15 psi. The boiler was drained, and then refilled for the pressure rinse with preheated demineralized water (105 F) containing 15 lb sodium sulfite, 10 lb TSP, and 10 lb of caustic.

The boiler was fired off and the pressure raised to 50 psig. At this time, the boiler was given a heavy blowdown. After restoring the water level, the pressure was raised, and the boiler blown down. This process was repeated, replenishing chemicals as necessary, until 250 psig was reached. See Table IV for pressures and chemical concentrations. It will be noted that the maximum silica concentration was 1.4 ppm, with the final turbidity approaching 35 ppm. This particular process was curtailed due to shortage of distilled water.

Two circulating pumps were run at all times, with the third one being placed in service prior to draining. The boiler was allowed to cool using fans and circulators and then drained under nitrogen pressure.

The boiler was inspected internally and found to be very clean, especially with respect to presence of black iron oxide. The interior surfaces did not have the appearance of raw new metal, but had a gray cast. The platen-wall tubes were flushed, internals, orifices, and secondary strainers installed, temporary connections removed, and the unit was ready for service.

Disposal of Cleaning Wastes

We may pause at this point to consider the disposal of the chemical cleaning solutions. This has become increasingly important due to the activities of various regulatory agencies governing stream pollution. In this particular case, the station is provided with primary and secondary ash lagoons, which are equipped with adjustable weirs. The chemical wastes were flushed to the primary lagoon for settling and neutralization. The effluent passed to the secondary lagoon, where they were impounded for further neutralization. After retention for approximately ten days, and after chemical tests were made, the impoundment was gradually released. The pH of the effluent averaged 6.9. This system has met with the complete approval of the Virginia State Water Control Board.

Experience of this company and of other companies dictates that steam lines should be thoroughly blown out prior to operation of the turbines. Severe damage to turbine blading has been reported despite use of strainers and preliminary blowing of the lines. It is important that high mass velocities be used if a thorough job is to be attained. A log of the blowout of the steam lines is included in Table V. Regardless of the thoroughness of the blowout procedure, it is deemed advisable to install stainless steel fine strainers at the turbine inlet for preliminary operation. These strainers are kept in service for 5–10 days of full load operation. After setting of the safety valves, the unit was ready for operational purposes. Due to low silica concentrations, it was not necessary to restrict load on the boiler. As a matter of fact, full load was carried on the turbine less than 48 hr after it was initially placed in service.

The make-up to this station is demineralized water and the entry point into the system is at the condenser hotwell. The pH of the make-up water is normally 8.8–9.0.

To minimize corrosion of the preboiler cycle and reduce the entry of corrosion by-products into the boiler, the pH of the cycle is maintained at 8.9–9.0 by use of cyclohexylamine. This volatile amine is fed continuously at the outlet of the deaerating heater. Continuous recording instruments show values of pH, conductivity, dissolved hydrogen, and oxygen content. It has been found that the dissolved hydrogen content is a direct indication of the rate of corrosion attack.

TABLE III—LOG OF POST-BOIL

Time	Pressure	SO_3	PO_4	SiO_2	Turbidity
3:00 P	...	88	27	Trace	...
5:15 P	425	80	16	Trace	33
9:30 P	400	80	13	1.3	24
11:30 P	400	80	18	0.3	24
3:30 A	400	77	16	0.7	11
7:30 A	400	80	18	0.2	20
11:30 A	400	64	20	0.5	37
1:30 P	400	58	14	0.6	24

TABLE IV—LOG OF PRESSURE RINSE

Time	Pressure	SO_3	PO_4	SiO_2	Caustic Alk.	Turbidity
8:00 P	0	75	...	0.4	133	55
8:15 P	25	72	...	...	125	72
8:30 P	35	72	22	1.4	112	62
9:00 P*	50	70	...	1.6	117	75
9:15 P*	50	74	...	...	108	55
9:30 P	67	70	18	1.1	123	45
9:45 P	100	67	...	...	115	53
10:00 P*	100	67	18	1.1	109	53
10:45 P*	150	64	17	1.0	109	49
11:00 P	200	60	...	0.9	101	44
11:40 P*	250	60	...	0.7	101	42
12:05 A	250	56	...	1.4	124	42
12:20 A*	250	...	...	...	...	...
1:00 A*	250	...	...	...	...	...
1:10 A	250	57	8	1.0	120	37

* Blowdown and refill.

While it is realized that the reaction rate of even catalyzed sulfite is low at the temperatures prevailing in the lower stages of feedwater heating, sodium sulfite is fed at the approximate rate of 0.05 ppm continuously at the condenser hotwell. This feed is in the form of a spray located between the lower level of tubes in the condenser, and the surface of the water in the hotwell. In this manner, the condensed steam must fall through a sheet of sulfite-treated water. The amount of sulfite fed is sufficient to maintain 1–3 ppm residual sulfite in the boiler water.

No difficulties have been noted or indicated from the usage of the feedwater containing the sulfite in these quantities as desuperheating water.

The pH of the water entering the economizer is raised by boiler water recirculation to 9.2–9.5 to afford more complete protection to the economizer surfaces.

Water Tests

The steam-condensate-feedwater cycle is analyzed daily for pH, conductivity, ammonia, and oxygen content by the laboratory personnel. More complete analyses including copper and iron are made on a greater number of sample locations on a weekly basis.

Control limits on the boiler salines are as follows:

Phosphate as PO_4	1–3 ppm
Caustic alkalinity	35–50 ppm
Sulfite as SO_3	1–3 ppm
Chlorides as Cl	5 ppm max
Silica as SiO_2	3 ppm max*

* Normally runs about 0.5 ppm.

All chemicals fed are C.P. grade, due to the fact that commercial grades were sometimes found to be contaminated. This was especially true of the sodium hydroxide, which occasionally was found to have considerably high quantities of silica contaminant.

The sodium hydroxide and phosphate are fed intermittently to the boiler drum. As previously indicated, the sulfite and cyclohexylamine are fed continuously to the feedwater cycle. The boiler salines are tested twice daily by the laboratory personnel. In addition, the salines are checked for alkalinity, phosphate, and sulfite residuals every four hours by operating personnel.

The report of a recent comparison of operational results obtained when using cyclohexylamine and when using morpholine was given at the Annual Meeting of the ASME last fall by Ristroph and Yorkgitis (2).

A summary of these results of feedwater control on Chesterfield No. 3 unit is shown:

	—Morpholine—			—Cyclohexylamine—		
Sample	pH	Fe, ppm	Cu, ppm	pH	Fe, ppm	Cu, ppm
Steam	9.06	0.005	0.001	9.04	0.002	0.001
Hotwell	9.06	0.006	0.005	9.04	0.005	0.003
19th Stg. Heater	9.05	0.007	0.006	9.09	0.007	0.003
17–19th Stg. Drips	9.07	0.007	0.005	9.08	0.006	0.004
17th Stg. Heater	9.06	0.007	0.004	9.09	0.006	0.009
14th Stg. Deserator	9.07	0.007	0.002	9.01	0.005	0.004
Economizer Inlet	9.07	0.005	0.002	9.12	0.005	0.004
Make-up	8.99	0.009	0.001	9.00	0.009	0.003

It will be noted that copper and iron concentrations are in all cases less than 0.01 ppm.

In conjunction with control of the pH of the steam-condensate-feedwater cycle, it is felt that it is also essential to keep dissolved oxygen concentrations at the absolute minimum attainable. This latter subject was elaborated upon in a recent publication by Grabowski (3).

TABLE V—BLOWOUT OF STEAM LINES

Piping Circuit	Extent of Blow, Min	Pressure Initial	Pressure Final	Blowing Rate, Lb/Hr
Main steam, north	2	425	390	220,000
	3	390	280	270,000
	4	400	290	200,000
	3	400	310	325,000
Main steam, south	4	400	350	310,000
	3	380	310	360,000
	3	400	290	350,000
	3	400	320	350,000
Cold reheat, north	2	430	410	350,000
	3	430	330	400,000
	3	430	360	380,000
Cold reheat, south	3	440	400	390,000
	3	450	340	430,000
	3	410	330	425,000
Reheater and hot reheater	4	580	550	425,000
	4	530	310	440,000
	3	550	330	440,000
	3	500	320	430,000
	3	560	370	450,000
	4	600	350	460,000

Conclusion

The author has attempted to present the present viewpoint of the Virginia Electric and Power Company relative to chemical cleaning and water treatment. The methods used at present are by no means static, and have been changed in the past, and will be further changed as new progress is made in these fields by the industry.

It is felt that chemical cleaning of the feedwater cycle and boiler is not only safe and feasible, but is justified on the basis of economics and equipment availability. However it should be done only under close supervision of competent personnel.

Rigid control of feedwater and boiler water conditioning is desirable, and results in reduction of corrosion, deposition in the boiler, and equipment outage. Efficient deaeration for removal of dissolved oxygen is essential to attainment of minimum rates of corrosion.

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PRELIMINARY PREPARATIONS OF THE STEAM-CONDENSATE-FEEDWATER CYCLE FOR INITIAL OPERATION OF A HIGH PRESSURE BOILER

1 Back-flush all tubes.

2 Install temporary test connections with adequate cooling coils.

3 Extend drum vents through roof of station to atmosphere.

4 Equip circulators for pressurizing from boiler feed pumps, and make necessary provisions to maintain water pressure to the stop and check valve at the economizer inlet.

5 Disconnect feedwater connections to header inside drum. Install temporary flanges with 1-in. orifices.

6 Make provisions to vent circulators if they should become gas-bound.

7 Provide nitrogen manifold and bottled nitrogen.

8 Install steam line to deaerator.

9 Provide necessary chemicals and store near boiler.

10 Provide explosimeter to measure hydrogen concentrations.

11 Provide suitable safety signs as required.

12 Provide test bench and necessary equipment.

13 Install thermocouples and provide clean bare locations for contact thermometer measurements.

14 Install suitable low-range gage on boiler drum.

15 Provide adequate personnel for test work and establish coordination of effort of operating, test, and treating personnel.

16 Provide adequate preheated water and/or means of heating treating water.

17 Provide check list for all valves or other connections whereby chemical cleaning solutions may enter equipment or lines other than those being treated. Appoint supervisory personnel to personally check, tag, or otherwise eliminate any possibility of this occurrence prior to beginning chemical cleaning.

18 Coordinate preparation of metal temperatures with arrival of treating personnel.

19 Provide permanent piping system for filling and draining boiler. Size must be adequate.

ABSTRACT OF BOIL-OUT PROCEDURE

Fill superheater with condensate.

Fill boiler to operating level with city water while adding the following chemicals:

Chemical	Per 1000 units
Activated sodium sulfite	0.8 lb
Soda ash	2.0 lb
Sodium hydroxide	2.0 lb
Trisodium phosphate	4.0 lb
Dowell detergent	0.6 gal

Start two circulating pumps and circulate for 15 min. Check chemical concentrations.

Fire boiler with light oil and slowly raise pressure to 50 psig. Maintain this pressure for 24 hr, with periodic checks on sulfite concentrations. After 24 hr, blow down boiler approximately 20 in. in drum, using blowdown valves alternately and maintaining 50 psig pressure. Refill to operating level. Maintain sulfite minimum of 50 ppm.

Repeat the blowdown and refilling procedure until satisfactory conditions of turbidity, alkalinity and silica are attained.

Cool the boiler and add sufficient chemicals to restore the original charge. Fire boiler and raise the pressure slowly to 200 psig and hold for 12 hr. Increase pressure to 400 psig and maintain for 12 hr.

At the end of this period, repeat the blowdown and refilling procedures until satisfactory conditions are attained.

Laboratory personnel should check for oil and chemical concentrations throughout the duration of the boil-out procedure.

ABSTRACT OF CHEMICAL CLEANING

1 Shut down boiler in normal manner. Run fans and one circulating pump to cool boiler.

2 Check temperature on main thickness of drum, and drum man-head. If temperature of main thickness of drum does not exceed 190 F, and man-head 175 F, proceed with the draining of the boiler. Drain maintaining nitrogen pressure of 5 psig minimum.

3 At the same time, the superheater should be flooded with condensate and kept overflowing during entire cleaning process.

4 Place temporary gage glass in service. Close and tag all valves whereby acid could get from the boiler proper to auxiliary equipment or piping. Make check list and be positive all points are covered. Some locations are: chemical feed, continuous blowdown, Yarway and bicolor water glasses, Penn manometers, valves to Bailey controls, Yarway remote level indicator, angle valves at economizer, drum level recorder, etc. Install blank on acid fill line that is common to other boilers, etc.

5 Open economizer recirculation valves wide.

6 Compartmentize A and B circulators with condensate from the hotwell pumps. Close and tag and disconnect (may use pig-tail between double valves, but be sure pig-tail valve is open) all leak-off lines. Provide pressure up to stop and check valve on feed line at economizer inlet.

7 Run boiler feed pump at minimum speed (500 psig), and close and tag all injection water supply at A and B circulators. This should prevent any possibility of acid leak-back into injection system.

8 If boiler temperatures are within the following ranges, start acid fill:

Drum 160–175 F at manhole head
Tubes 140–175 F

If temperatures are lower than specified, fill water with 200 F water and circulate with C pump. Drain when correct temperatures are reached, using nitrogen.

9 Using city water (demineralized water if available) fill boiler with acid solvent at 165–170 F max boiler inlet temperature. Acid solvent strength to be 6 per cent with Dowell A-30 inhibitor, and $^1/_2$ per cent Dowell Y-1 intensifier. Fill boiler within one inch of top of temporary gage glass, checking temperature and concentrations of solvent while filling.

10 After boiler is full, run C pump for ten min. Repeat circulation at hourly intervals, but only for five-min duration. Sample solvent for acid strength, and check metal temperatures after each shutdown. Have fire hose available in case of acid leaks.

11 Close drum vents and begin draining boiler to ash pond six hr after completion of fill. Drain acid as rapidly as possible, maintaining nitrogen pressure of five-

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psig minimum. Keep ash pit seal flooded to overflowing during acid drain. Close each drain valve immediately as soon as nitrogen issues from valve.

12 Upon completion of acid drain, begin filling boiler with deaerated condensate or demineralized water (city water may be used on this first rinse only if necessary) to same level as acid fill. Maintain nitrogen pressure.

13 When boiler is full circulate with C pump for 15 min. Shut down pump, drain as in section 11, maintaining minimum pressure of 5 psig with nitrogen. Check pH of drain water. Repeat 12 and 12 until rinse waters reach a pH value of approximately 5 or higher. Use only deaerated condensate or demineralized water for all rinses after first rinse outlined in section 12.

14 When boiler is empty, begin fill for postboil. Introduce one per cent solution of soda ash, 15 lb sodium sulfite, and 15 lb TSP into boiler using temporary dissolving tank and acid pump through economizer. (Close suction header fill valve prior to pumping chemicals.) At the same time, if possible, fill boiler with boiler feed pump to acid level with water from deaerator. Drain back to firing level using nitrogen. Circulate with C pump for 15 minutes. Check sulfite concentration.

15 Place Penn manometers in service.

16 Fire boiler with light oil, using C pump, to 400 psig. Vent nitrogen to atmosphere when pressure reaches approximately 20–25 psig.

17 Hold pressure of 400 psig for 24 hr, shut down fires. Cool boiler, using fans and circulator. When drum pressure reaches 5 psig, begin maintaining nitrogen pressure of 5 psig. When temperature reaches a suitable level, predicated upon the available temperature of water for next refill (to avoid thermal shock), shut down fans and circulator. Drain boiler as in section 11, maintaining nitrogen pressure.

18 When boiler is empty, fill boiler with water from deaerator. At the same time, introduce 10 lb of sulfite, 10 lb TSP, and 10 lb of caustic (previously dissolved) into boiler as in section 14. Fill boiler to acid level, drain back to firing level, maintaining nitrogen pressure.

Fire boiler to a pressure of 50 psig. Blowdown 20 in. in drum. Refill to firing level, adding chemicals to maintain pH of 10 min, with minimum of 10 ppm SO_3 residual, through chemical feed pumps. TSP may be added to maintain original level if desired. Gradually raise pressure in 50-psi increments and repeat blowdowns, alternating blowdown valves and refilling each time. Repeat until 250 psig is reached.

Check turbidity and silica after each blowdown and log. Continue blowdowns until turbidity is 40 ppm or less. Drain boiler as in section 11.

19 Open boiler for inspection, remove all temporary connections. Flush all tubes in platen wall. Flush lower drums if inspection indicates necessity. Replace plugs on chemical feed line and blowdown line in drum. Prepare boiler for startup.

International Combustion Conference Convenes in Cambridge

AS a highlight feature of the ASME's Diamond Jubilee celebration the first International Combustion Conference was held on the campus of the Massachusetts Institute of Technology in Cambridge, Mass., June 14–17, 1955. This particular meeting was jointly sponsored by the ASME and the British Institution of Mechanical Engineers and the joint sponsorship carried through to the sessions.

There were approximately 400 registrants with roughly 50 from overseas. These registrants witnessed the first attempt on the part of the ASME to employ the reporter technique practiced by the British in presenting technical papers. Briefly the technique consists of an individual, designated the reporter, reviewing all submitted papers and then condensing them to a five-minute individual summary. If all the papers on a given program lend themselves to comparisons or contrasts the reporter stresses these differences or agreements in viewpoint and thereby stimulates audience discussion. The sole purpose of such a procedure is to liven up the presentation of technical programs.

Combustion Fundamentals

"The Chemistry and Physics of Combustion," Part I by **Sir Alfred Egerton,** Univ. of London, Part II by **Professor O. A. Saunders** and **D. B. Spalding,** Imperial College, London Univ.

The mechanical engineer uses combustion for producing heat in many kinds of equipment including power plants of all kinds, and furnaces and heating plants. In internal-combustion power plants, the heat is required in the products of combustion for the purpose of producing work by expansion, but in all other applications the heat is transferred from the combustion products or fuel bed to the material to be heated, whether it be water, steam, air, or the charge in a heating furnace. The majority of these applications employs a steady combustion process fed with fuel and oxygen from external supplies, but an important exception is the piston-type internal-combustion engine in which the process is intermittent and repeated, the flame being extinguished and relit every cycle. Naturally, the different forms of combustion exhibit many different features, but in this paper the authors try to point out the common chemical and physical basis of all applied combustion processes. The history of applied combustion, the authors state, has perhaps shown too strong a tendency toward specialization. For example, much work has been done on the intermittent processes of the piston engine, and the true relation of the steady-flame process has not always been clarified.

The fundamentals of combustion are both chemical and physical. The starting point is of course chemical, the nature of the reactions and the amounts of heat produced being determined in the first place by the chemical properties of the reactants. But the rate at which the reaction occurs is nearly always influenced by physical considerations, such as the rate of supply of oxygen to the burning zone by either molecular diffusion or turbulent mixing. The physical and chemical factors must therefore be considered together, although it is found that, in various applications, one or the other is often predominant in controlling the rate of combustion.

The engineer's requirement is, briefly, to know how to design his combustion chamber to develop the required distribution of heat release in a steady manner in the case of continuous furnaces, or in the required time in the case of intermittent processes. He wants to know what factors, chemical or physical, constitute limitations to what can be done. Information, to be of much value to him, must be quantitative rather than qualitative, and one of the greatest difficulties in applying existing knowledge of combustion chemistry to practice lies in the scarcity of quantitative data concerning chemical-reaction rates. Nevertheless, it is possible to show in a general manner how these rates affect the general problems of flame control and extinction, in anticipation of the full quantitative understanding of the subject which is the aim of chemists and physicists alike.

The physical processes of importance in combustion are those which result from contact between neighboring substances of different temperature and composition, namely, conduction and diffusion, either with or without turbulent mixing. These processes are relevant because it is, frequently, steady flames that are being dealt with. If a given substance is being consumed by reaction at a particular point and yet the state is to remain steady, a steady supply of the substance to the point must be provided; this is the function of diffusion. Similarly, the heat generated by reaction must be carried away if the local temperature is not to rise; this is the function of conduction.

The interplay of the chemical and the physical processes is a recurrent theme in Part II of the paper. Sometimes one or other of these processes is dominant, sometimes both together govern the overall rate of combustion. The authors deal first with a case in which physical and chemical processes combine (flame propagation), leading finally to a number of important cases in which physical processes are dominant.

The paper "Scientific Principles of Combustion and Their Application" by **Bernard Lewis,** and **Guenther von Elbe,** Combustion and Explosives Research, Inc., surveys the present knowledge of scientific principles in the field of combustion processes. This includes chemical kinetics as a means of understanding the chemical changes occurring during combustion; the propagation and structure of combustion waves as a means of understanding the processes occurring in combustion chambers. The application of such principles to combustion practice is considered. It is noted that, although in general only minor applications have hitherto been made in the development of technical combustion processes, newer developments can be expected to make increasing use of the knowledge that has developed in the last decade.

It may be true that the scientific profession has had little share in the basic engineering developments that

utilize fuels and combustion processes, and perhaps decisive developments have occasionally been helped rather than hindered by ignorance of the complex physics and chemistry involved.

Whether or not today's science is adequate to cope with modern combustion practice is another matter. Why should this be so? Because combustion research is still largely in its infancy.

This being the situation, vexed practitioners in the field of combustion have occasionally condemned fundamental research as pure waste; others, taking a more constructive view, demand that the engineer should tell those engaged in research what it is that he needs to know. The research worker who specializes in the field of combustion will be inclined to raise the question whether the practicing engineer is fully cognizant of the complexities of the situation, and he will suggest instead that he be left alone to work out the needed basic concepts and principles without which the science of combustion will forever remain in its infancy. There is excellent reason to believe that he will be able to do so in this research-minded age, and that in time he will emerge with such convincing proof of the utility of the scientific approach that his critics will be satisfied.

In this paper the authors take stock of what scientific principles have already emerged in the field of combustion, to what extent such principles are already rationally applied to various combustion practices, and what future applications may be expected to develop.

Ralph A. Sherman, and **William T. Reid,** Battelle Memorial Institute, in their paper "An Appraisal of Combustion Research" reviewed research in combustion with the objective of appraising its effect on today's practice in the utilization of fuels.

Today, although the mechanism of the combustion reactions is not yet completely understood, coal is burnt at rates of up to 100,000 lb per hr under a single boiler smoothly and continuously. The efficiency of combustion is often as high as 99 per cent, and the overall efficiency in the transfer of the heat in the coal to that in the steam is over 90 per cent.

Over the years the number of researches on the combustion of solid fuels has been many, and the resulting publications have been correspondingly numerous. It has quite naturally fallen into two general categories; first, the more basic research, such as studies of the mechanism of the reaction and rates of reaction of coal or of coke; and secondly, engineering research, in which the events that occur in fuel beds or in suspensions of fuel in air are studied experimentally, either in full-scale operating equipment, or in smaller-scale equipment that simulates full-scale furnaces.

That much of the research should be of the latter type results from the fact that coal is a complex fuel which, in the process of combustion, gives off volatile combustible gases leaving a carbonized residue far different in character from the original fuel that entered the experiment. If one starts with beds of discrete particles of bituminous coal, there will quickly be beds of larger pieces resulting from the caking together of the coal particles. If one starts to study the reaction of particles of a given size in suspension it is found that one soon has hollow spheres of carbon of quite different size and density from those with which one started.

For these reasons, many of the researches of the basic type have had to be carried out on carbon or coke and not on coal. The results will thus not be directly applicable to the combustion of coal. They will be of more direct applicability to the combustion of coke, which is, of course, of great importance in the blast furnace, in the cupola, and in many other uses.

Within this century the fluid fuels, natural gas and products of petroleum, have assumed an ever-increasing importance in supplying the world's needs for energy. For the generation of steam, for metallurgical and other industrial-process heating, and for comfort heating, both fuel oil and natural gas have taken over a large share of the energy market. For the internal-combustion engine, gasoline and Diesel oil are almost indispensable to the world's economy. If it be assumed that each of the some 54 million automotive vehicles of the United States is capable of an output of 100 hp, their potential capacity is 5.4 billion hp or fifty times the installed capacity of American electric-utility plants.

In the development of the burners for boilers, for open-hearth furnaces, for cooking stoves, for residential furnaces, for internal-combustion engines, and for gas turbines, it would be assumed that a tremendous amount of scientific and engineering research on combustion of the fluid fuels must have been conducted. A survey of the literature confirms this assumption. The number of reports of research on combustion of oil and gas exceeds by far the number on solid fuels. Furthermore, the scientific and technical periodicals of all countries continually carry papers that present the results of research on the combustion of liquid and gaseous fuels.

Because of the tremendous volume of this work and because the papers by Egerton, Saunders, and Spalding (1955) and by Lewis and von Elbe (1955) at the present conference deal largely with these subjects, the present paper touches on this field to a much more limited extent than it does on that of solid fuels. Such a treatment is also the only appropriate one for the present paper, because the literature in general deals with the scientific aspects of combustion and touches but little the engineering application.

The interest in the phenomena involved in the oxidation of gases ranging from hydrogen and carbon monoxide through the gaseous and readily gasified liquid hydrocarbons has intensified in the past twenty years because of the need for advances in high-intensity combustion for military applications. However, even before this time the field had been appealing for fundamental research. As Townend (1954) has well expressed, ". . .research into combustion problems makes wide demands on scientific understanding in its broadest sense, whether in the physical chemistry of kinetic processes, the physics of flow states and wave phenomena, or in engineering science. Also, few fields seem to call for a greater sense of adventure and yet at the same time patient exploration. . . ." For these reasons, this type of combustion research has attracted not only the fuel and mechanical engineer, but also the physical and organic chemist, the physicist, and the mathematician. Any other interest in fuels or an interest in the possible engineering application of the results is unnecessary for this research.

Boilers American Papers

The trend toward centralized, fully automatic control

of boilers and other combustion equipment has resulted in a strong demand for effective flame-failure-detection equipment, and stimulated advancement in the design of the instruments themselves, and in the techniques of applying them, according to **W. D. Stevens,** Babcock & Wilcox Co. in his paper "Instruments As Applied to Detection of Flame Failure." The proper use of the new equipment available, in the author's opinion, makes possible the reduction of operating personnel with an increase rather than a decrease in safety.

There are two distinct classes of instrument for detection of flame failure, as Mr. Stevens reports them. The first is television, which transmits to the operator a visual picture of the flame itself and in some installations, not only the presence or absence of a flame, but of such conditions as flame stability and clear or smoky fire.

The second class of flame-failure detection instrument includes the various types capable of detecting the presence, absence and, perhaps, the relative strength of a flame, and of translating this intelligence into an electric impulse which may be used to sound an alarm or shut off the fuel. Instruments of this class are used more widely than television, particularly on small or medium-size boiler and furnace installations due, in part, to relatively low cost but more so because of their ability to be applied to automatic fuel shut-off, and thus to reduce the amount of operator supervision required, or to eliminate entirely the need for a regular operator.

The principal basic elements used in flame-failure detection are covered. These include: the stack temperature element, the photo-electric cell, the flame rod, the lead sulfide cell and the combustible analyzer. In each instance some of their inherent strengths and limitations as primary sensing elements are described as well as their range of application in flame-failure detection systems.

Mr. Stevens then submits some field experience on the application of these flame-sensitive elements to oil and gas burners. A number of installation and operating tips, with appropriate sketches to improve the effectiveness of these various elements are advanced. For example, with oil firing the author considers the sensitivity of the lead sulfide cell too great to afford discrimination between a good and a bad fire when it is mounted on the burner front and equipped with a large enough orifice to permit supervision of the gas lighter.

Under these conditions, states the author, the lead sulfide cell will distinguish between the presence or total absence of the flame but that is all. For single burners with fully automatic on-off control a separate scanner in the rear wall is recommended to give a reasonable degree of discrimination between a good fire and an unsatisfactory one. In this case the rear scanner operates in parallel with the burner front scanner. The front scanner supervises only the lighting cycle and is cut out of service when the main oil fire is on.

When the subject of flame-sensitive equipment application to multiple burner oil- and gas-fired furnaces is discussed, Mr. Stevens places the present commercial ceiling at units up to outputs of 100,000 lbs of steam per hr and with no more than two rows of burners in a furnace. Further, Mr. Stevens emphasizes the dangers inherent in careless selection or arrangement of the flame-sensitive or auxiliary equipment. In addition the author stresses the needs for supplementary interlocks and the advisability of automatic lighters complete with relays and interlocks. Many of the details of fuel line valving, with accompanying sketches for both gas- and oil-firing and a list of the desired functions of a suitable flame failure safeguard in the way of electrical arrangements have been supplied by the author.

The CO Boiler

Oliver F. Campbell, Sinclair Refining Co., in the paper methods of Disposal and Elimination of Petroleum Refinery Waste Gases" outlines for a background the fact that the modern oil refinery is confronted with the disposal of various kinds of refinery waste gases without polluting the atmosphere. The usual method of disposal, as he explains, is to pass these waste gases through a high-temperature auxiliary-fired furnace where they are completely oxidized, diluted, and dispersed in the atmosphere through an adequate stack to prevent their being an air-pollution nuisance. For the great majority of refineries this is a practical and satisfactory solution to the problem. But this paper presents some special methods of disposal of waste gases by burning and dispersion in the atmosphere which have proved practical for several installations of the author's company.

The first type discussed is a large special waste-gas eliminator equipped with waste-heat recovery. In either event, the obnoxious gases are rendered harmless owing to the combination of the combustion process, the resultant product dilution and dispersal at a high elevation at a higher temperature.

Modern refineries are usually equipped with catalytic cracking units, which upon regeneration of the catalyst, emit to the atmosphere the products of combustion from the burning of the carbon and the hydrogen (called "coke") deposited on the catalyst during the cracking operation. The combustion process for the regeneration of the catalyst normally produces an appreciable percentage of carbon monoxide. Mr. Campbell explains that the regenerator is designed primarily to restore the cracking activity of the catalyst by burning off the carbonaceous deposit of carbon and hydrogen. This cracking catalyst is de-activated by sintering at high temperature, so the regenerator-bed temperature is usually limited to 1,100 F for a synthetic catalyst and 1,070 F for a natural catalyst. Excess oxygen is ordinarily low because of the cost of compressing the regenerative air.

This last factor would make it highly desirable, in the matter of fluid-unit operation, to have an even higher carbon monoxide production, since burning carbon to carbon dioxide requires twice as much oxygen as for burning carbon to carbon monoxide.

The author's Company conceived the idea of developing a waste heat boiler to recover the combustion heat of the carbon monoxide gas given off in catalyst regeneration and render a harmless gaseous product at the stack discharge. To make this waste heat boiler worthwhile two basic premises were laid down for the design: (1) The unit must completely burn all of the carbon monoxide in the regenerator flue gas. (2) The design must be such that the capital cost and the operating cost could be justified by the fuel saving. This last named premise made it necessary to ascertain that economic conditions of time, temperature, turbulence and excess oxygen could be established for the complete combustion of a CO burning gas of 15 Btu per cu ft.

Pilot-plant work had shown that by the use of supplementary fuel and with thorough mixing with air, the very dilute carbon-monoxide-bearing gas could be completely burned with low excess oxygen at a reasonable temperature level. Economics dictated thorough mixing for the commercial unit to ensure complete combustion with minimum auxiliary fuel and air. Another important decision was whether the combustion chamber should be a water-cooled or a refractory furnace. The water-cooled furnace offered a lower capital cost for the combustion chamber. However, the heat absorption from the combustion chamber increased the auxiliary-fuel requirements, thereby requiring a larger boiler which would compensate for the added cost of the refractory combustion chamber. Further, the refractory furnace offered minimum auxiliary-fuel consumption with maximum certainty of maintaining combustion temperature at a reasonable level. So the refractory furnace was selected for this, the first commerical unit to be built.

Several ideas for mixing the in-coming fuel were examined. The method that seemed to offer the best mixing with the simplest equipment was to inject the carbon-monoxide-bearing gas into the primary furnace tangentially through several inlet ports at different levels. This would set up a swirling cyclonic action to mix the carbon-monoxide-bearing gas thoroughly with the auxiliary fuel and air which would be fired through several burners located at different levels.

It was decided to fire sufficient auxiliary fuel to raise the carbon-monoxide-bearing gas to a temperature of approximately 1,450 F without taking credit for the heat of combustion of the carbon monoxide. It was realized that the carbon monoxide's combustion heat would raise the furnace temperature above 1,450 F, thereby providing a safe design and operating margin. Once the carbon-monoxide-bearing gas of low Btu value was completely burned, the problem of recovering the heat, it was felt, could be easily solved by a conventional water-tube boiler and economizer.

The carbon-monoxide boiler as developed, consists essentially of a cylindrical refractory furnace and a secondary water-cooled furnace followed by an economizer. It includes a bypass arrangement so that the boiler may be shut down without shutting down the fluid catalytic cracking unit. Even though pressurized boilers were in their early stages of development at the time of the design and the author's company had no experience with pressurized furnaces, Mr. Campbell states, the very nature of the carbon monoxide boiler dictated pressurized operation because the carbon-monoxide-bearing gas was already under several pounds of pressure and the great volume of gas of low Btu value made induced-draft operation excessively expensive.

The carbon monoxide gas injected through twelve tangential inlet ports symmetrically located with four ports at three different levels. Twelve auxiliary-fuel burners are symmetrically located with four burners at each of three levels. The top level of auxiliary burners is located above the top level of the carbon monoxide ports so that the carbon-monoxide-bearing gas has to pass through a layer of auxiliary fire to leave the primary furnace.

The secondary furnace is a conventional water-wall furnace of a single-pass boiler. The arrangement of the top-supported secondary furnace over the bottom-supported primary furnace requires a water seal to provide for the downward expansion of the secondary furnace and the upward expansion of the primary furnace.

This CO boiler produces 340,000 lb per hr of saturated steam at 700 lb per sq in pressure with full production of carbon-monoxide-bearing gas and 220,000 lb per hr with no carbon-monoxide-bearing gas available so that sufficient steam is available for starting and shutting down the fluid unit. This boiler was the oil industry's first direct-fired unit to recover with the sensible heat and the heat of combustion from the exit flue gases of the high-temperature regenerator.

In general, the advantages of a carbon monoxide waste-heat boiler in a catalytic cracking unit as the author lists them are:

(1) Independence of outside sources of steam and energy during operation, shut down, or start up.

(2) Complete control of steam production for the fluid catalytic cracking unit under the supervision of the fluid operators.

(3) Steam production at high pressure and temperature, which decreases the steam requirements of prime movers of fluid catalytic cracking units.

(4) Prevention of pollution of the atmosphere by the carbon monoxide.

(5) Avoidance of unburned hydrocarbons or malodorous gases (or other gases that may cause air pollution) escaping to the atmosphere.

(6) Flue gases conditioned for subsequent removal of particulate matter.

(7) An excess steam production for other refinery uses thereby reducing the load on refinery-fired boilers.

(8) Elimination of an added fired boiler to start and shut down the fluid catalytic cracking unit.

In addition to the carbon monoxide boiler of the author's company at Houston, another oil refining company started a carbon monoxide boiler in June, 1954, of the same basic design as the one at Houston and the results obtained have been substantially the same as for the Houston boiler. The differences in design are that (1) the carbon monoxide boiler started in June, 1954, is equipped with an attemperator-type steam superheater, whereas this first one started in October, 1953, has no super-heater; and (2) the later carbon monoxide boiler is equipped with additional burners in the secondary furnace whereas the earlier carbon monoxide boiler has no secondary-furnace burners.

The author's company, he reports, is building a second carbon monoxide boiler of different design from the one at Houston. This boiler, of the cylindrical-furnace design will maintain a high primary-furnace temperature even though the furnace is of water-wall construction. To maintain this high primary-furnace temperature which minimizes auxiliary-fuel burning, the primary-furnace tubes are covered with 2 inches of plastic refractory held in place by studs on the tubes. This new-type boiler, to handle carbon-monoxide-bearing gas from an existing fluid catalytic cracking unit, is equipped with a steam superheater, an attemperator, and an economizer. It is said to occupy less space and be appreciably cheaper than the carbon monoxide boiler at Houston. An interesting feature of this cylindrical carbon monoxide boiler is that the

external carbon-monoxide-gas-bearing ducts have been eliminated. In addition, this new-type boiler does not require a water seal between the furnaces.

Furnace Design

Otto de Lorenzi, Combustion Engineering, Inc. begins his paper "Furnaces for Low-Quality Solid Fuels" by defining the use of the terms rank and grade as they are applied in comparing different coals. As he points out there is, however, no well-defined line separating low-quality coal from high-quality coal. The type of fuel-burning equipment, design of furnace, arrangement of heat absorbing surface, as well as character of plant load, may frequently be responsible in a large measure for the quality category into which a given coal falls.

This paper confines itself to relatively large pulverized-fuel-fired units such as are usually found in the more modern power-generating stations. There are included, also, operating results from two medium-size, stoker-fired units such as are used for smaller utility installations. A number of the fuels employed in the sample installations are bituminous coals, in the majority of which sulphur content ranges from 2.5–4.5 per cent, ash from 8.0–17.0 per cent, and ash-fusion temperature from 1,900–2,150 F. In addition, lignite-burning installations are also discussed, and, for these, sulfur varies from 0.3–2.4 per cent, ash from 5.5–8.4 per cent, and ash-fusion temperature from 2,000–2,200 F.

The principal characteristic features of modern pulverized-fuel-fired units, as the author sees them, have been developed through a process of evolution, based on wide variations in fuel quality and under many different operating conditions so that the designer must choose the proper combination which will assure satisfactory and trouble-free service with the lowest-quality coal, not only presently available, but also that which may be necessary to burn at some future date.

In the author's opinion correct approach to the design of a large steam generator is to employ a combination of furnace volume and water-cooling so that corresponding heat-absorption rate will assure—at or somewhat above rated capacity—a furnace-outlet temperature below that necessary to use, but it must be sufficiently high at the minimum control point to provide the desired steam temperature. But during operation, Mr. de Lorenzi points out, furnace walls become coated, and tend to slag up so that the designer has to reckon with this problem of fireside fouling. The problem is held by the author to be of such gravity that he devotes the major portion of his paper to the designer's choices for an effective means of regulating the furnace outlet temperature to maintain steam temperature at a safe level.

As Mr. de Lorenzi describes it the difficulty follows this pattern. With the high heat-liberation rates, owing to reduction in ash-fusion temperatures and increases in ash content, there is a tendency to more rapid accumulation of slag on furnace walls. Close spacing of tubes in boiler and superheater zones results in high gas-entering velocity with attendant accelerated plastering and rapid build-up of slag on convection surfaces. Soot blowing and hand lancing are only partially effective in dislodging and removing these fireside deposits. Availability and capacity factors are thereby reduced and outage, for external cleaning of heat-absorbing surfaces, must be scheduled at relatively frequent intervals. To combat these conditions, and thereby lengthen in-service periods, the operator can obtain a limited degree of furnace-temperature regulation first by increasing excess air and, finally, by reducing firing.

Steps have been taken, with the more recent designs, to minimize difficulties resulting from downward trend in coal quality. Furnace walls are usually completely water-cooled and, where necessary, are also increased in area so as to lower heat-liberation rate. Spacing between adjacent tubes, as well as tube rows, of boiler bank and superheater is increased so as to reduce gas velocity and improve accessiblity for cleaning. The effects of these two changes are a lowered furnace-outlet temperature, minimized accumulation of fireside deposits and an increase in the interval between scheduled outages.

The furnace-outlet temperature of a steam-generating unit is a direct function of total heat absorbed by the furnace water-walls. This absorption, is in turn, a function of heat-liberation rate per sq ft of effective water-wall area, furnace wall cleanliness, excess air, fuel firing rate and method of firing. Operating data from many in-service installations provide the necessary factors from which the combustion engineer can design a steam-generator furnace and accurately predict its performance.

Modern high-pressure, high-temperature turbo-generators have introduced, however, another factor which directly affects furnace performance, that is, the insistent demand for constant steam temperature over increasingly wider ranges in capacity.

In the majority of large post-war units, both non-reheat and reheat types, the entire saturated-steam production is completed in the water-cooled furnace. This fact, in addition to the heat-liberation rate, establishes furnace-outlet temperature. Thus, for a given set of conditions, which include capacity,steam pressure and temperature, feedwater temperature, excess air and efficiency, it is necessary to supply a definite amount of heat to the furnace. Then, if all saturated steam is generated in the furnace water-wall surfaces, resulting gas temperature will be a function of heat remaining in the products of combustion at furnace outlet. The variable factor under these conditions is the amount of effective furnace water-wall area required to maintain furnace-outlet temperature at a level which assures continuity of operation at rated continuous capacity for the unit, regardless of any desire to maintain constant steam temperature down to some partial-load point. For furnaces with burners in a fixed position, outlet temperature will decrease with reduction in capacity; consequently, steam temperature will also be lower unless compensated for by an increase in gas-flow rate or modification in heat absorption. The principal means available to accomplish this are either some form of bypass damper or a desuperheater.

Earlier designs employing bypass dampers have operated successfully over moderate capacity ranges. The desire, however, further to lower the minimum-load point requires the use of either excessively large superheaters or higher entering-gas temperatures. The first of these choices was uneconomical because of greatly increased cost, the second because of reduced in-service availability resulting from increased fireside deposits on furnace walls as well as on boiler surfaces.

A solution was, therefore, to employ the principle of

differential firing whereby, as capacity is decreased, an increasingly greater proportion of the fuel is burned in the upper furnace zone. Operating in this manner, in the author's opinion, reduces overall effectiveness of furnace water-cooling surface and raises furnace-outlet temperature. By supplementing wide-spaced burners with gas recirculation, the temperature-control range can be improved considerably.

Gas recirculation offers advantages of its own. It provides the designer with a means for controlling both superheater performance and gas temperature at the furnace outlet. This is the manner in which it works. Varying percentages of flue gas are withdrawn from the unit, at some suitable point between boiler outlet and air-heater inlet, and then reinjected into the furnace. Effectiveness, as a means for maintaining constant steam temperature over a wide capacity range, depends on the location and manner of introducing the recirculated gas into the furnace. With proper application it is possible to provide designs in which furnace-outlet temperature, at maximum capacity, is sufficiently low to avoid excessive slag deposits, even with low-quality coal, and yet maintain constant steam temperature over a wide capacity range. The superheater will have minimum surface because its proportions are based on conditions at maximum output rather than some fractional capacity point. Mr. de Lorenzi stresses that it should be remembered gas recirculation adversely affects performance, because both draft loss and boiler-exit temperature are increased as a result of higher gas flow through at least a part of the unit.

There is, however, as the author shows, still another solution. This one, the use of tilting, tangential burners employs differential firing in its truest form. To secure the variation in temperature at furnace outlet required to maintain constant steam temperature over a desired capacity range it is necessary to make relative changes in the area of heat-absorbing surface. Inasmuch as the furnace of a steam-generating unit is a rigid structure, these changes cannot be made by continually varying its proportions. The requirements can be approached through tangential firing with vertically adjustable, or tilting, burners because the combination of radiant and convection transfer is greater than with any other method of firing owing to sweeping action of flame-envelope over furnace-wall surfaces. Regulation of furnace-outlet temperature is accomplished through changes in burner-nozzle tilt. By directing the incandescent turbulent mass of burning fuel toward the upper zone of the furnace, the required higher outlet temperatures can be obtained during periods of light load or when water-wall surfaces are dust-free. For increasing loads, or when walls are coated with sintered dust, greater portions of the entire furnace can be used to maintain outlet temperature at a desired level by tilting the burner nozzles downward as required.

Mr. de Lorenzi furnishes installation experiences for several of these methods, including slag-tap and hopper-bottom designs, plus a typical reheat application.

He concludes his paper with descriptions of stoker fired units using bituminous coal and lignite.

Firing Methods

The paper "Effect of Fuel Properites on Firing Methods" by **L. R. Burdick** and **R. C. Corey**, U.S. Bureau of Mines, discusses fuel-burning practice in the United States for stationary steam-generating units above 5,000 lb of steam per hr capacity. The discussion includes a brief description of the combustion equipment available and the fuels for which they are best suited.

The authors base their appraisal of the individual fuels on the physical state of the fuel, such as gaseous, liquid, or solid; on the solid fuel properties, such as rank, caking characteristics, range of sizes, volatile content, ash, ash-softening temperature, slag viscosity.

The gaseous fuel sold in large quantities for steam generation is natural gas. Firing methods for this fuel, the authors state, are not affected by the properties of the fuel itself, such as composition, specific gravity, and heating value, since the extent of variation of these properties is rather limited. The method selected is based on other considerations such as the gas pressure available, the size of the installation, type of furnace, and its use in conjunction with other fuels.

The liquid fuels sold for steam-generation purposes, called fuel oils, are oils obtained by the refining of petroleum. The refiners adhere to standards set up by the petroleum industry and the National Bureau of Standards. These are known as "Commercial Standards for Fuel Oils, Bureau of Standards CS12-48," and specify the fuel properties pertinent to the handling and combustion of the various grades marketed. Installations of the sizes under consideration in the reported paper, normally use only the two heaviest grades in these standards, which are called No. 5 and No. 6 fuel oils. The properties specified in the standards for these two grades are flash point, per cent water and sediment, per cent ash (No. 5 only), and viscosity. The firing methods are not affected by these properties of the fuel since the main types of oil burner in use for units above 5,000 lb of steam per hr are designed to handle both of these grades of oil. Selection from the types of burner available is dictated by other considerations such as the size of unit and the type of service.

The solid fuel sold in quantity for steam generation is coal and receives most of the author's attention. This solid fuel consideration includes all ranks from anthracite to lignite, inclusive. A number of known properties of coal have a bearing on the firing method chosen for a given installation. These are rank, caking characteristics, range of sizes, volatile content, ash content, ash-softening temperature, and slag viscosity. Other properties and constituents determined in the laboratory, such as moisture, grindability, and sulfur, which primarily influence design and operation, as distinguished from methods of firing, are not considered in the discussion. The authors find it convenient, owing to the size limitations of some types of equipment, to discuss the firing methods by equipment-size groups.

In general, there is good agreement among plant designers on the firing methods that should be used for coals of the various ranks. Although, in connection with the other properties, there is divergence of opinion, based on viewpoint and operating experiences, in regard to the numerical values that are significant in the selection of equipment, the following general statements are made by the authors:

(1) The caking characteristics of coal have been expressed for many years by terms such as light, medium, moderate, and heavy caking. The laboratory determination of the free-swelling index is considered to have

promise as an indication of the caking action of coal in fuel beds, but the authors believe there is a great need for published correlation data. However, in connection with the selection of chain- or traveling-grate stokers to burn bituminous coal, it is generally felt that this type of stoker is suitable for coals with free-swelling index up to No. 6.

(2) Stokers for bituminous, sub-bituminous, and lignite coal are sold to use a single-screened coal, that is, all the coal that passes a given size of round-hole screen. Typical recommended sizes are $^1/_4$ in. × 0 for spreader stokers, 1 in. × 0 for chain- or traveling-grate stokers, $1^1/_4$ in. × 0 for end-cleaning underfeed stokers, and 2 in. × 0 for side-dump underfeed stokers. While size consist of coal is important in these applications, its determination is difficult and there are few published data correlating it with stoker performance. The top-size designation for coal size has been found to be the most practical one to use.

(3) Although the volatile matter, of itself, is not ordinarily a limiting factor in the firing method selected, better results are often obtained with side-dump underfeed stokers when the volatile matter of bituminous is above 27 per cent, and practically all bituminous coal suitable for the chain- or traveling-grate stokers exceeds 30 per cent.

(4) Since the ash content of most of the coal on the market does not exceed 15 per cent, this also is not a limiting factor except that, in conjunction with the size of the unit, it has a bearing on the type of ash discharge selected. Continuous ash discharge is often considered when the ash content is expected to be above 10 per cent.

(5) Although the entire range of coal ash-softening temperatures may be handled with a certain degree of satisfaction by underfeed stokers when properly applied, 2,400 F is often considered to be the dividing point between a high and a low ash-softening temperature for these types of stoker. In general, the other types of fuel-burning equipment are more reaily applied than the underfeed stoker for coals with ash-softening temperatures below 2,400 F.

There has been a tendency toward lower continuous-grate heat-release rates than formerly used for plant design. Coal producers and designers striving for trouble-free performance and insurance against future depletion of high-quality coals have been largely responsible for this change.

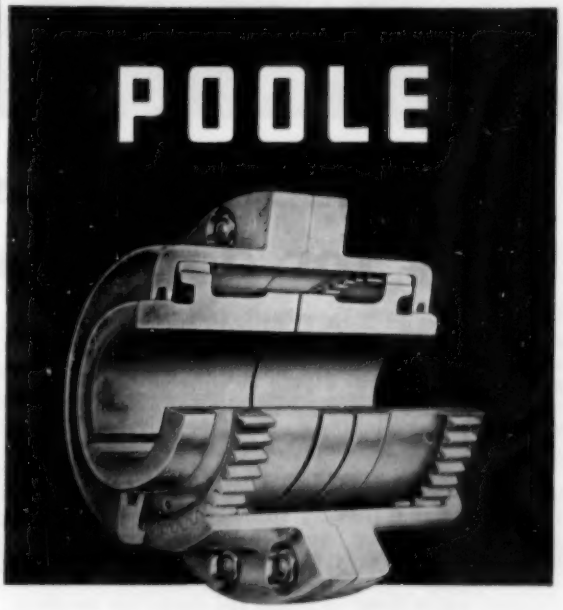
Recent developments, the authors point out, indicate the potentialities of using as boiler fuels the coke or char residues from new low-temperature-carbonization processes, and of the sale of the liquid and gaseous products to reduce fuel costs for large steam-generating units. These developments include engineering studies of methods and of the economics of low-temperature carbonization of bituminous coals, the reported successful operation of a 50-ton-per-day bituminous-coal-carbonization pilot plant, and the commercial application of low-temperature-carbonization process for low-rank, non-caking coals. A large-scale fluidized-bed plant to dry lignite for power-plant use is in operation at Rockdale, Texas. A proto-type low-temperature fluidized-bed carbonizer has also been installed to test the economic feasibility of extracting tars and coal chemicals from the dried lignite prior to burning to reduce the cost of steam generation by sale of these liquid products in open markets.

There is a substantial amount of wood waste used for steam generation in the vicinity of mills that process timber and its products. This waste material includes bark, shavings, sawdust, sander dust, and wood pieces of various sizes. The wood pieces are chipped by machine to a fairly uniform product called "hogged fuel." This waste fuel is burnt on horizontal, slightly sloping, or inclined grates in a Dutch-oven furnace. Hogged fuel or bark also may be fired by spreader stokers in conventional boiler furnaces.

Power Plant Gas Turbines

During the past ten years, use of the gas turbine has advanced so rapidly that many thousands of machines have been built for use in military aircraft, and for other uses ranging from portable fire pumps to large power-generating units. A large proportion of the units now in service are, however, suitable for use only with clean gaseous or distillate fuel. In order to compete with steam plants for large-scale power generation, it is apparent that the gas turbine must burn the same low-cost fuels used by the steam plant, namely, residual fuel oils and coal. The paper, "Coal Firing for the Open-cycle Gas Turbine: A Comparison of Methods" by **Herbert R. Hazard,** Battelle Memorial Institute, discusses some of the technical aspects of burning coal in the open-cycle gas turbine.

The difficulties which may be anticipated in combustion equipment for the gas turbine result from operating requirements rather than from differences in operation under pressure.



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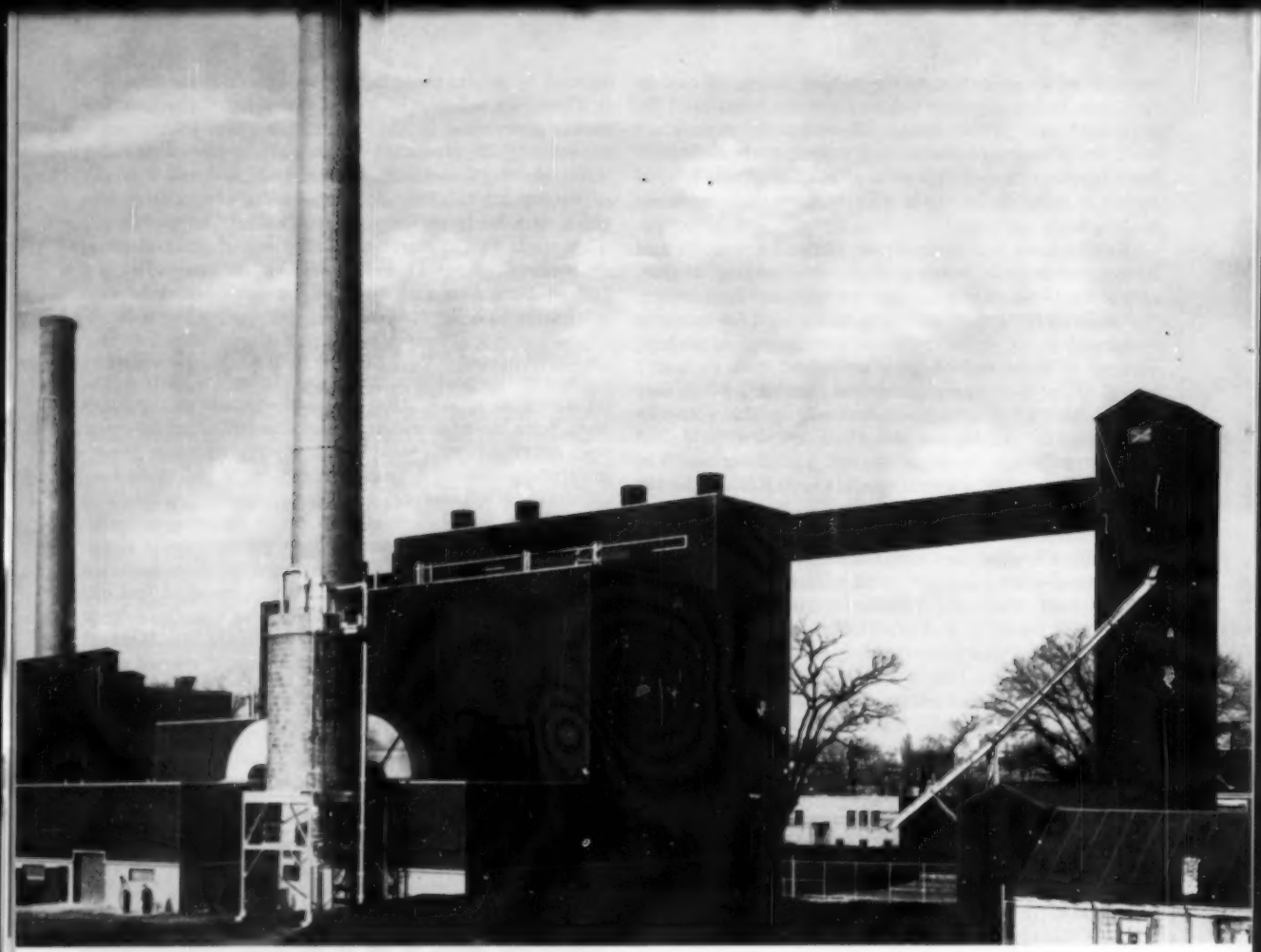

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Industry's Responsibilities in Training Engineers for Nuclear Engineering Work*

By R. W. KLECKER

Allis-Chalmers Manufacturing Company

If the nuclear power plant is to achieve its anticipated growth in the utility industry, engineers skilled in nuclear technology will have to be trained in increasing numbers. The author points out that the nuclear engineer serves as the connecting link between the scientists who have discovered the laws of nuclear behavior and the builders who will construct the reactors of today and the future.

WHAT are industry's responsibilities in training engineers for nuclear engineering work? Before this question can be answered, we must first establish what nuclear engineering is and determine what characteristics, if any, make it different from other engineering fields.

Atomic energy projects, and specifically the building of a nuclear power plant, require intensive research, development, and design programs before the construction phases begin. Each of these projects needs personnel with varying degrees of knowledge in the fields of physics, metallurgy, electronics, and heat transfer; just to name a few. In no other type of enterprise is the educational background requirement so inclusive of all the basic sciences.

Atomic energy fields, like the weapons projects, or even, the smaller programs like one to develop health, physics, instrumentation, or electromagnetic pumps or liquid metals, require comparable study and test programs involving similarly trained manpower. In each case the personnel must have a composite knowledge and experience which spans the educational range from pure scientific theory and basic information on one extreme to more commonplace manufacturing know-how on the other. For instance, it is not uncommon for a nuclear physicist to sit side by side at a conference table with a steam plant engineer, a servomechanisms designer, or a heat transfer analyst.

In this discussion, education is defined as the acquisition or accumulation of knowledge and/or experience regardless of whether it is obtained at a formal educational institution, or as on-the-job training, or by some other means.

In this paper, the educational background of the personnel engaged in designing and building a typical nuclear power plant will be specified in a general sense to establish what the profession of nuclear engineering includes. This should provide a representative picture of the art and allow conclusions to be drawn as to just what is a nuclear engineer. It is not implied that all members of this group belong to one industrial or governmental organization. In fact, the converse will more likely be true. That is, the main group is apt to be made up of smaller sub-groups who specialize in only certain phases of the overall program but yet who work together as a team. In making this study, we will find that a nuclear engineer should have a rather broad educational background. It will be shown that we desire him to be a very versatile person; part physicist, part mechanic, part mathematician. The nuclear engineer must serve as a connecting link between the theoreticians and the builders of atomic energy devices. He should have a working knowledge of all the ramifications of reactor theory and design, system controls, economics, and materials.

Then, having established what a nuclear engineer is, or at least what we wish him to be, it is planned to explore the capabilities and limitations of a sample engineering graduate. By comparing their respective educational backgrounds, it will be shown how industrial training is utilized to integrate the novice into the final group and bridge the gap between engineering school and nuclear engineering practice.

It will be the purpose of this paper to describe the requirements for the complete education of a nuclear engineer while emphasizing responsibilities of industry in training engineers for nuclear engineering work.

The Education of a Nuclear Engineer

The design and construction of a nuclear power plant requires a variety of technological and professional skills. In an attempt to catalog these talents and to ferret out the nuclear engineer, it is planned to make use of educational spectrums.

These figures are designed for comparison purposes and it is hoped that they will serve as a pictorial aid in visualizing educational scope in the same sense that a plot of signal amplitude versus frequency serves in electrical engineering or the spectrum of neutron density versus neutron energy serves in reactor physics.

First, a somewhat arbitrary division of the educational range is made in which formal scientific education is shown at one end of a scale and manufacturing know-how on the other. Proper discretion will allow subjects which are neither purely scientific nor purely industrial practice to be located along this scale at definite points between the two extremes. Then the ability of an individual to utilize these specific educational topics for the design of a nuclear power plant can be drawn as the

* Presented at The American Society for Engineering Education 63rd Annual Meeting, Pennsylvania State University, June 20–24, 1955. Slightly abridged.

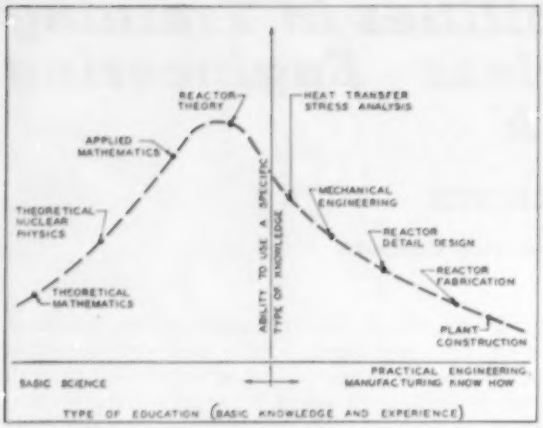


Fig. 1—Example of an educational spectrum of an individual charged with making reactor power calculations

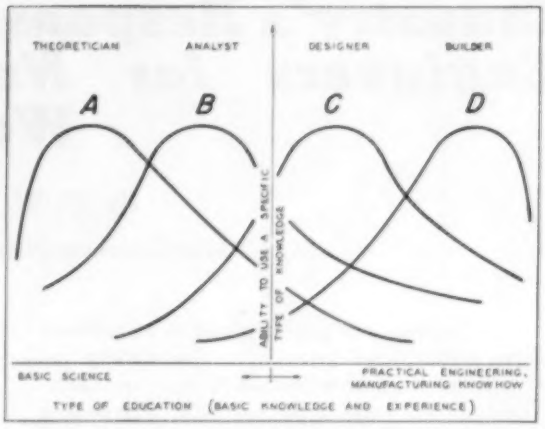


Fig. 2—Educational spectrum of four typical members of a reactor power plant design group

ordinate to the educational scale. In this manner an educational spectrum can be established to describe the abilities of an individual in the various fields of scientific and engineering training which are utilized in nuclear power plant design and construction. Fig. 1 is an illustration of the educational spectrum of a reactor physicist. It is an example of where certain specific educational areas might fall along the educational scale. The length of the abscissa represents the extent of the educational background required for the complete design of a reactor power plant. The scale is adjusted so that the more scientific subjects such as theoretical phsysics appear to the left and such subjects as industrial engineering or education gained by practical experience in the design room or the manufacturing shops appear to the right.

The ordinate of the curve is intended to represent the degree or amount of knowledge an individual has concerning the particular educational topic and his ability to put it to practical use. Note that the ability of this individual is quite high in the range where analytical techniques are needed but that he lacks experience in the engineering and manufacturing skills required to build a reactor. Another person trained in practical engineering and with experience in manufacturing know-how would supplement the physicist. This man's educational spectrum would have a maximum on the right of this diagram.

People whose educational spectrums fall to the left are assumed to be trained in inductive thinking. Their calculations or theories estimate or predict reactor and plant performance. Personnel whose curves fall to the right verify the work of those on the left by making practical applications of the findings of the scientists.

Even though there may be many exceptions to the rule, a typical individual is likely to be well informed or skilled in only one specific area of the educational range as we have defined it and to a comparatively lesser extent in unrelated areas. In other words, he is able to make an appreciable contribution to only certain phases of the overall nuclear power plant design. Hence, his ability will be a maximum within some area of the educational range and somewhat less at other points.

A similar set of curves can be drawn for each of the engineering sciences. However, in this paper, their use will be restricted to nucleonics which is assumed to be inclusive of all the basic sciences. These diagrams could be made more descriptive if they were extended in more than two dimensions but this would be at the expense of simplicity.

In Fig. 2, four members of a nuclear power plant design team are portrayed to illustrate the four major subdivisions of engineering and scientific knowledge utilized in reactor power plant design and construction. All curves are shown of about the same maximum height to stress the fact that all phases of the program are equally important. Degree of ability and breadth of educational background, as shown, are understood to be relative. Even though these individuals are typical of specific groups, any other member of the team might possess abilities and educational background which would place him almost anywhere along the abscissa and the measure of his abilities might require a much less general or less smooth curve.

Member A of Fig. 2 is a theoretician. He represents the nuclear scientists, the chemists, the solid state physicists, and the theoretical mathematicians who supply the basic information, nuclear data, the concepts, the original derivations of the equations which describe the life span and behavior of the neutron in a reactor and the methods by which to solve these equations. Member A is likely to have a higher formal education. His contributions will be directed mainly toward the development of the reactor and its auxiliaries primarily because the art of steam plant design has already been more positively established over the course of many years.

Member B is an analyst who is representative of a relatively large group. His specialties are likely to be a good understanding of mathematics and the equations which describe the basic laws of nature. He reasons primarily in terms of dynamics instead of statics. The analyst aids in translating theory into feasible operational designs. In nuclear work it is his calculations which establish such parameters as size, composition, or critical mass of the reactor, or the thickness of the radiation shield. In other engineering fields associated with reactor design he determines the stability of the control

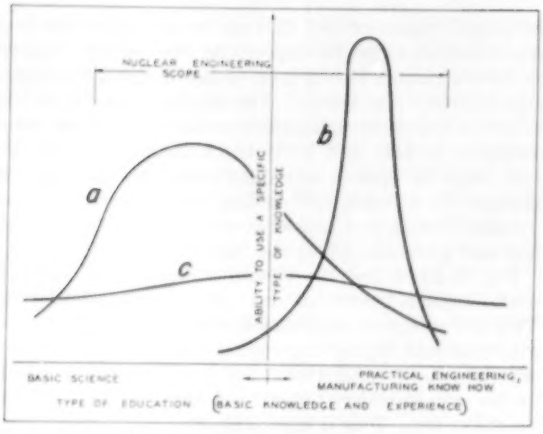


Fig. 3—Educational spectrum of three engineers illustrating variations in educational background.

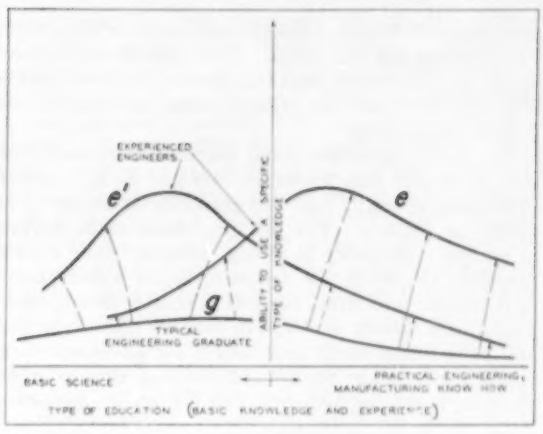


Fig. 4—Educational spectra illustrating the development of experienced engineers.

system or the temperature distribution in an odd-shaped reactor fuel element.

Member C represents another large group. He is the design engineer who knows how materials and machines must be put together, or the metallurgist who specifies the materials to be used. His knowledge stems from practical experience as well as from formal education. The designer must realize how the specifications he proposes affect the economics of the entire system. Often time he must balance the cost of an item or a particular design against the benefits to be derived from it. Much of his education originates in observation of engineering tests or in studying test results.

Member D is the industrial or manufacturing engineer who builds the reactor power plant by utilizing the blueprints provided by the designers. He is the engineer who secures the materials and oversees the erection of the reactor, the reactor buildings, and so forth. In other words, he is the final fabricator of the plant which culminates many years of work and the dreams of the other team members.

A few of the jobs necessary in the design and construction of a nuclear power plant have been named and classified according to the type of educational background required for their performance. Not mentioned were many others which fit somewhere along the educational line. There are for instance the many research workers, computor operators, test engineers, and others who perform important technological functions in the reactor art. Many engineers also devote time to management duties, supervision, report writing, and other less technical but necessary jobs.

It is believed that nuclear engineering work will be found near the center of the educational range as it has been defined and will include both the analyst and the designer. The scientist on one end of the scale and the manufacturer on the other need not be considered as nuclear engineers but this does not exclude nuclear engineers from performing some of their tasks.

It will be noted that the educational background of the nuclear power plant personnel portrayed in Fig. 2 is rather broad and extends outward in both directions from the specialty of the individual. This is a very desirable qualification for a nuclear engineer. For illustration, consider the three engineers shown in Fig. 3. Engineer a represents one who is suggested as having a desirable educational background. He knows his specialty quite well but also knows enough about other fields to appreciate the problems of his neighbor. Thus, he fits nicely into a well-rounded organization, needs a minimum of supervision or coordination, and can work with his teammates to recognize and contribute his proper share to the overall design. W. E. Kelly[1] says, "Our problems in utilizing nuclear energy cut straight across the lines of conventional training. We use a specialist and we need him, but the big contributions come from men with solid foundation training who have understanding of related fields." For comparison, consider also the extremes b or c. Engineer b is very much a specialist. He knows his field as an expert but does not appreciate how it may fit into the overall picture. Although there are some uses for people with this type of talent, in general, they require the coordination efforts of other people to integrate them into the team. A reactor power plant design group made up entirely of personnel with limited educational scope would be difficult to manage and rather inflexible.

The other extreme is engineer c. He has a knowledge about many subjects but a somewhat limited one. The problems of putting together a design group solely of these people are quite obvious because their abilities are too limited. Possibly engineer c is a novice and if he is willing to learn he has a definite place in a reactor study group as an assistant to the more experienced engineers. In time he will develop the necessary skills he needs. It will be shown later how industry can develop the education of these engineers to provide manpower who can shoulder the responsibilities of future reactor designs. Other uses for people with this type of talent might be in report writing, management assistance, or similar duties to relieve the more technically inclined personnel of these chores.

In the early years of the reactor business there was a dearth of skilled technical and professional people who were familiar with more than a few aspects of the com-

[1] "Engineering Problems in the Utilization of Atomic Energy," *Journal of Engineering Education*, October, 1952.

plete design. Hence, a design group in those days would be somewhat less that ideal. Even now there is a shortage of personnel with broad nucleonic education and so both industry and the colleges must continue to sell nuclear engineering.

An individual's educational spectrum may vary from time to time in that his duties vary and he may acquire proficiency in a new field and gradually lose some of his ability in another. For instance, some of us working in nuclear engineering have had occasion to use electromagnetic theory in the design of liquid metal pumps, heat transfer and stress analysis in reactor design, servomechanism theory and electronics in reactor control, and have found many applications for advanced mathematics in reactor physics calculations, thermal stress analysis, and field plotting. This is nuclear engineering.

The Education of a College Graduate

Now that it has been established what areas of knowledge are utilized or needed in reactor design and what type of education is desirable for individuals engaged in nuclear engineering work, let us turn our attention to the educational background of a sample engineering graduate.

In recent years many educators and employers have suggested that the engineer be given a better education in the basic sciences and that his courses be taught as liberal subjects in a professional curriculum rather than as narrow specialties. This approach is definitely recommended especially if the student has an inclination toward nuclear engineering work. Hence, in this discussion it is assumed that the young engineer has an education of fairly broad scope and somewhat near the center of our educational scale.

The students' abilities will differ depending on the intelligence, aptitude, and length of training of the individual. Graduates with higher than baccalaureate degrees and those who have had the benefit of university level nuclear engineering courses will be better equipped to perform certain phases of the analytical engineering but most will still be inexperienced in the industrial manufacturing practices which appear to the right on the educational scale. Hence, it is recognized that educational spectrums of young engineers will vary considerably in both scope and degree of ability. Also, as mentioned earlier, engineering graduates have individual differences which must be considered such as temperament, mental alertness, mechanical comprehension, and analytical ability. In many cases, the new engineer on entering industry is not always aware of his true capabilities and not always sure where his interests lie.

Curve *g* of Fig. 4 is assumed to be representative of a sample engineering graduate. It is compared with curves *e* and *e'* which are chosen to be representative of typical nuclear engineers. One is a design engineer and the other is an analytical engineer and since these represent the majority of all cases, either may be considered as the goal of the novice. Usually after an individual has had a chance to settle himself in his new profession he will either be inclined toward one or the other depending on his interests and abilities. One will tend to intrigue him while the other will lack certain features which challenge his initiative.

A definite spread between the spectrums of the experienced engineers and that of the graduate has been made intentionally to impress on the young engineer that even though he has secured his diploma, his education has only just begun. The student must be willing to accept the opportunities for further development made available to him and to look for others. During the first years he spends in industry this is especially important, for a young man willing and eager to learn can usually always find someone with experience to teach him and guide him along the right paths of thinking.

Fig. 4, illustrates the extent of training an engineer must acquire before he can call himself experienced. This new education is not small or insignificant but rather extensive and highly important. The task of developing the education of the young engineer falls not only on his own shoulders but also on those of the company he works for. This is especially true in the field of nuclear engineering where many of the opportunities for further development exist only in industry or industry-operated government facilities.

Industry's Responsibilities to the Engineer

The growing need for nuclear engineers with a broad background of knowledge in the basic sciences and reactor theory, and experience in the art of reactor design and construction has long been recognized by many people. As early as 1948 when the nuclear powered submarine programs began to get underway the government began training programs to educate the people it needed. Later, formal schools were set up at Oak Ridge and other government laboratories. The most publicized of these and perhaps the one with the most ambitious program is the Oak Ridge School of Reactor Technology. The government monopoly in the training of nuclear engineers and scientists was a necessity at this time because of the classified nature of the subject matter and the lack of appropriate teaching facilities elsewhere.

Within the past few years, universities have begun taking over a large portion of the academic training of personnel in reactor theory and basic science. Industry too, is recognizing the need for training more personnel in the reactor art and has begun contributing to their education. This is done in a number of ways; one, by the normal training procedures already established by the companies for other engineering personnel and two, by loaning personnel experienced in other fields to the government laboratories or other organizations who are doing nuclear work so that they may acquire first hand experience to broaden their knowledge of nuclear engineering while contributing their specialty.

A third means of giving men in industry experience is now possible by means of government-authorized study programs which industry can undertake at its own expense. These programs give the company access to the government files of classified information on reactors and atomic energy in general. Of course, the men who use these files must have the proper AEC security clearance and the company must demonstrate a need for the information.

Once the young engineer is on the job, it is up to industry to provide the necessary incentives and challenging work to maintain his interests for usually an engineer with the personality and temperamental characteristics required for the computational and me-

chanical comprehension of research and development work of any sort may be easily discouraged or become disinterested if his duties are allowed to become too routine or too simple for him. Industry must also afford proper recognition for his accomplishments since, traditionally, the inevitable reward of ability and effort in creative engineering has been technical achievement which is brought about by the pride of authorship and the proper recognition by other members of the engineering fraternity. The engineer must also be shown how his job fits into the company organization and how its successful completion contributes to the overall program which might in some cases be the design of a reactor power plant. Industry must also provide adequate supplementary facilities such as laboratories to aid the engineer to fulfill his duties to the company.

These are some of the intangibles. Then too, the leaders of industry should set good examples of professional engineering ethics and install in the young engineer the philosophy of teamwork. In an undertaking as large as a nuclear power plant design which is one involving a multimillion dollar effort and a great many people, there is no place for individualism and unethical practices at any level. On the more practical side, the very nature of reactor design calls upon a great variety of technological skills all of which are seldom, if ever, found in any one person. Hence, teamwork is the answer.

Now let us see how industry goes about the more formal training of the personnel it needs to fill in the team for nuclear engineering work. Many of the larger industrial organizations have had for many years a system for training graduate engineers before ultimately assigning them to definite engineering tasks. The engineering training program at Allis-Chalmers is typical and I will describe it briefly and assume it to be representative of industry as a whole.

Allis-Chalmers started its graduate training program over 50 years ago (1904) and has followed a policy of continuing to improve it from time to time. About 6 years ago we began administering psychological tests to some of the young engineers on a scientific basis for counseling the students and guiding them into assignments for which they are best fitted. The company recognized that engineers can achieve greater success if they are assigned to jobs utilizing their greatest interests and abilities. When he is on the graduate training program the young engineer is given an opportunity to do several types of work including engineering analyses, time studies, machine design, manufacturing, test work, sales, or even personnel work in the many departments of the company. There is ample opportunity for these men to find a real interest, since Allis-Chalmers manufactures approximately 1600 engineering products. The duration of the training course is flexible but allows up to two years during which time the young engineer may spend a few months each at about 10 to 15 different jobs. It has been reported that this training costs the company from $5000 to $10,000 per year per man. The same training is available to all engineers.

Part of the training includes formal courses in specific subjects. In general, however, the graduate is assigned as an assistant to an experienced engineer who devotes part of his time to aid the novice to learn more about the specific task he is then employed on.

If he has reasonable qualifications and interests in nuclear work, the young engineer can ask to be assigned to the company's Nuclear Power Section. This department was organized in 1949 and since that time has acquired most of its engineering talent from graduates of the company's training program. Under the guidance of a few of the older and more experienced engineers of the company, who incidentally at that time had had no previous nuclear power plant experience, the younger staff of the Nuclear Power Section assumed responsibility for many research and development projects for the government's atomic powered submarine program. It was necessary for these people to improve their education along the lines of nuclear engineering and reactor technology by night school courses, company sponsored lectures, library research to carry on their work.

In addition to on-the-job training such as has been mentioned, many companies subsidize postgraduate educational courses at nearby universities. These companies recognize the value of advanced engineering knowledge to industry. Such an arrangement makes it possible for the young engineer to combine study and research with practical experience in connection with the analysis and working out of on-the-job problems. The engineer thus continues to build specific abilities and also keeps abreast of the rapidly changing developments in his field. Moreover, it also makes possible the visualization of practical work in proper perspective against an actual background of economic and technological change, a procedure which is usually impossible during the average undergraduate course in engineering. Giving the engineer monetary assistance in a postgraduate program is also deeply appreciated by the student and encourages him to seek postgraduate degrees. This increase in his basic or specific knowledge aids both the individual and the company.

Industry's Responsibilities to Itself and to Society

Why does industry spend tens of thousands of dollars toward the formal education of one of its engineers and contribute in other ways toward his general educational development? Is industry altruistic or playing the role of a benevolent father? Definitely not. Industry does this because it is good business to do so.

As has been mentioned previously, there is a vital need for experienced nuclear engineers with a broad education. To obtain these men, industry must train them. Any program which a company undertakes will either succeed or fail depending on the caliber of the personnel responsible for it. Mr. Alfred P. Sloan of General Motors Corporation made a statement at a stockholders' meeting that brings this point clearly into focus. He said, "In our own great industrial organization and in the vast industrial structure of the United States, the same bricks, the same mortar, the same machine tools are available to everyone. The difference between a successful and an unsuccessful corporation lies in the men who comprise it."

Right now nuclear power is becoming one of the biggest of all businesses. Many millions of dollars and the time of many engineers and scientists are being spent each year for its development. Various programs are being carried on by industrial groups as well as by the United States and foreign governments. Some of the industrial programs are specifically for the training of personnel and the investigation of the business opportunities.

"Energie" Visits the Emil Adolff 1112 F Steam Power Plant at Reutlingen, Germany*

This article describes the visit of the editor of the European publication, *Energie*, to the German industrial plant of Emil Adolff, bobbin and spool manufacturers. This power plant includes a recent installation of a Sulzer Monotube steam generator operating at 1425 psig and 1112 F, and an Escher-Wyss axial-flow back-pressure turbine exhausting at 140 psig.

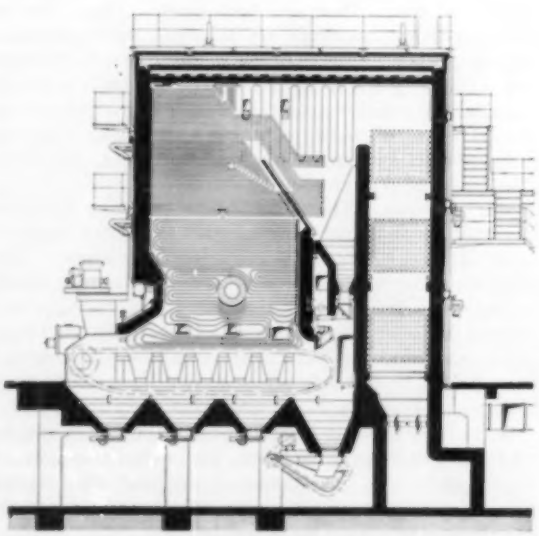
PAYING a visit to Reutlingen we had the opportunity to inspect the 1112-F industrial steam power plant of Emil Adolff, which has now been in service for one year. Chief Engineer C. Veit provided us with all the information we desired concerning the construction and the maintenance of this highly interesting plant. A look into the power plant indicates the progressive engineering approach of this company which as early as 1936 was operating a 1425 psig plant with a Sulzer Monotube Steam Generator and 1425 psig back-pressure steam engines. This installation was one of the most modern of its day and has remained in service for more than 18 years (over 125,000 hours). Increasing demands for power and heat in recent years have necessitated the construction of a new plant with correspondingly higher capacity. In 1950 the decision was taken to build an extension to the steam power plant, the principal features of which are the following.

1—Sulzer Monotube Steam Generator 1425 psig, 1112 F, steam output 25 tons per hr, with fully automatic pressure and temperature control.
1—Low-pressure steam transformer plant (accumulator); working pressure 140–115 psig, steam output 25 tons per hr.
1—Escher-Wyss single-casing, axial-flow, back-pressure steam turbine with an impulse wheel with partial admission and eight impulse stages.

Working pressure 1425 to 140 psig steam temperature 1094–1112 F.
Rpm = 10,000 to 3000
Direct coupled to a 3200-kw three-phase-current generator 3,200 kw (Siemens-chuckert-herke).

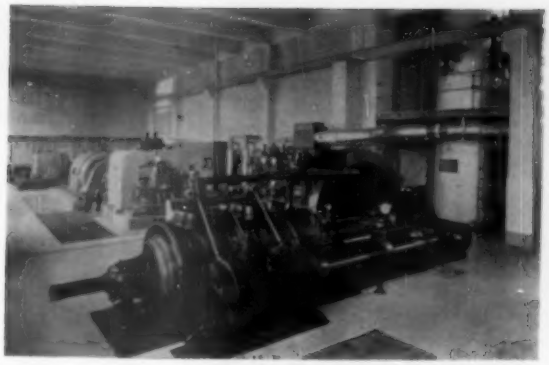
It is of interest to note that the heat and power supply for the entire factory comes completely from back-pressure operation of the 1112-F plant and that this plant has already been running for 7000 working hours without trouble and without making any special servicing demands. This pioneering achievement in the field of power and heat opens up new possibilities for increasing economy in the construction of industrial steam power plants, especially as the steam and power demands of industrial plants grow larger.

The basic layout of the plant in connection with the automatic steam generator control can be seen from Fig. 5: from the high-pressure steam generator (1) the steam is led at a pressure of 1425 psig and a temperature of 1112 F by way of the regulating units to the high-pressure turbine (2) and thence by way of secondary steam reheater (3) and high-pressure feedwater heater (4) to steam transformer 7; here the conversion of the remaining primary waste-steam heat into secondary or heating steam for use in the factory takes place. All the condensate flows from steam transformer 7 to storage tank 5, whence it is again conducted to the high-pressure steam generator (1) by means of the infinitely variable piston feed pump. Thus the high-pressure steam circuit is closed and requires but a very small amount of condensate makeup. This layout has the advantage that the high-pressure part which requires the purest water possible always works with the same water, i.e., to make up the leakage and blowdown loss it is sufficient to add but a very small amount of condensate, and this is possible without any complicated treatment. A larger and continuous amount of makeup is required by the secondary side of the steam transformer; but here there is not so great a demand for "pure" water. For the treatment of this feedwater a simple lime-soda softening plant is sufficient. With this arrangement a satisfactory solution was found to the very delicate problem of feedwater with high-pressure steam power plants; it also made possible at the same time a higher power output, be-

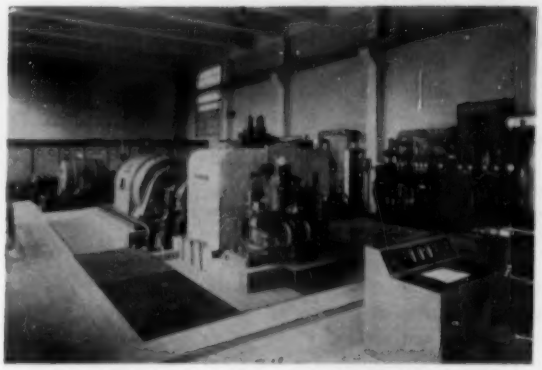


1—Section through Sulzer Monotube steam generator

* Translation of article which appears in *Energie* published in Munich, November 1954, Vol. 6, No. 11.



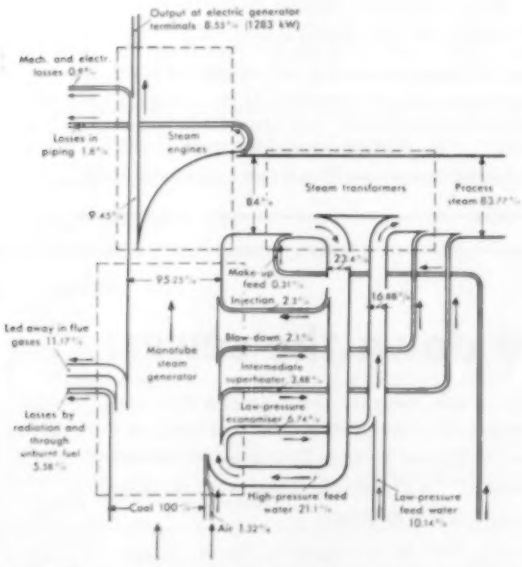
2—Prime movers at Emil Adolff plant: 1420-psig steam engine; new turbine with aluminum sheet casing background



3—View of the new turbine, a single casing, axial flow, back pressure design

cause the steam transformer, high-pressure feedwater heater and secondary steam superheater all to a certain extent act as preheat stages and promote an increased steam circulation in the primary part. In the present case for the production of power there is available the increased adiabatic temperature drop from 1112 F and furthermore an increased steam circulation by way of the back-pressure turbine.

In its construction the 1112 F plant is notable for the neat, clean exterior of steam generator, control station and steam transformer plant and for its small space requirements in relation to capacity. It was possible to contain the entire plant in the old, existing boiler and power-house so that all parts were still quite visible and easily accessible. The 1112 F steam generator is, as can be seen from Fig. 1, drumless and its inner structural elements comprise only tube nests and coils, which are connected up to the fully automatic steam-generator control system. The main connecting points between the tube nests, tube coils and steam collectors and likewise parts of the injection and blowdown equipment are set outside the steam generator in an easily accessible and visible place. The 1112 F plant is fired by a KSG traveling grate stoker with fine adjustment. The steam generator has an outer covering of sheet iron which has been given a coating of bright aluminum paint; this color sets off the 1112 F plant to advantage.



4—Heat flow and thermal balance of original steam engine plant installed in January 1936

It was possible to set up the 1112 F turbine plant likewise without cramping in the old power-house on the spot where earlier a low-output steam engine had been located. The steam turbine involved the greatest uncertainty in the new power plant. A certain amount of experience had been gained from the building of gas turbines as regards the behavior of heat-resistant steels, but none regarding the design and working of shutoff and regulating devices, flange connections, stuffing-boxes, etc., such as are essential with the 1112 F turbine. This turbine was therefore not merely a problem of material but equally one also of design, whose solution was rendered considerably more difficult on account of the behavior and the properties of the highly heat-resistant steels; it was, however, necessary to make the turbine casing together with rotor, regulating and shut-off devices, completely out of special heat-resistant austenitic steel with a high creep limit. Little could be seen from the outside of the special design of the steam turbine, since important parts such as stop valves and regulating valves, connecting tubes, flanges, etc., were concealed by the aluminum sheet casing.

The interesting behavior of the new materials was revealed by the first trial runs during which it was at first not possible to bring the rotor, which was not turning quietly, up to full speed. A scarcely measurable curvature was the cause of this disturbance. After stopping and cooling down the machine, the curvature had completely disappeared; unfortunately within a short period of time it was not found possible, using a heat-treatment technique, to remove the structural tensions so as to prevent a repetition of the curvature during the next trial run. The makers of the turbine now applied the technique of applying pressure to the rotor on one side and so giving it a bias in the opposite direction to the curvature. The result was striking: with no difficulty whatsoever the steam turbine could be accelerated to full revolutions and add or drop load with remarkable

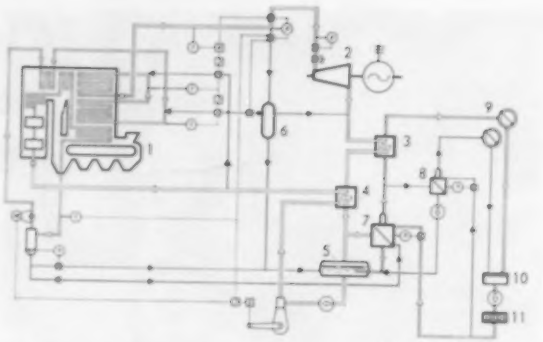
lack of difficulty. This is proved by, among other things, the fact that a small coin with a perfect edge placed upright on the bearing covers of turbine and "Maag" gear will at different loads remain standing on its edge.

From the instrument readings it can be seen that the turbine is actually run with steam of 1425 psig and 1112 F at 10,000 rpm. What is meant by steam superheated to 1112 F is most impressively demonstrated by a peep-hole in which the live-steam piping appears as a glowing dark red.

That the solution of the difficult problem of the 1112 F plant has been especially successful is evidenced by the perfect running of the plant, which now, as previously mentioned, has already been operating without irregularity for a full year of over 7000 hours under highly fluctuating load conditions. As regards servicing and attendance, the plant makes surprisingly few demands; attendance has been placed in the hands of a staff comprising simply engineer mechanics and stokers. Only occasional checks are made by a higher authority.

To check its capacity the whole plant was subjected to acceptance tests by the T.Ü.V.* for several days, which established that the guarantees of capacity and efficiency both with the steam generator and the turbine were being fulfilled and in part even substantially exceeded.

The Emil Adolff 1112 F plant has provided further evidence that even medium-sized industrial power installations can today make use of high-pressure and highly superheated steam successfully and without undue risk.



5—Basic control diagram of the recent turbine extension operating at 1420 psig, 1112 F.

* Technischer Überwachungsverein (Stuttgart)

Air Pollution Control Association Meets In Detroit

Some 500 registrants attended the recently concluded annual meeting of the Air Pollution Control Association in Detroit, Mich., May 22–27, 1955. This particular meeting's technical program featured highly specialized sessions confined individually to separate phases of the various major fields of interest in air pollution control ranging in subject matter from effect on plant life to operational aids in equipment performance.

From the wealth of material presented there were two papers of special significance to the steam power field. One, by **Gordon H. Strom,** of New York University, entitled "Scale Model Wind Tunnel Experiments on Stack Gas Dispersal," was actually a motion picture giving further information on the work underway at NYU's 3½ ft dia by 7 ft experimental wind tunnel. In the opinion of the author second to the "in-person" observation of an actual experiment the movie camera record is an excellent means of showing the effects on smoke plumes of systematically varied atmospheric and plant variables whose behavior affects the solution.

Kalman Steiner of the G. Hoffberger Co., Baltimore, Md. gave the second of these papers of interest to the power field, "Burning Heavy Fuel Oils." Mr. Steiner began his discussion with the explanation of the attempt on the part of the oil industry to introduce standardization in both the manufacture and the marketing of fuel oil. But the basic facts of life, namely, that the heavy fuel oils are residual fuels and owe their low price to this condition, work against the establishment of any rigid set of specifications for this fuel. With this as a starter the author comes to grips with specific operating problems. As a case in point he cites that "no question of pumpability arises with No. 5 oil. With No. 6 oil, we have not only the problem of atomization once the oil arrives at the burner, but also the problem of getting it there. Two factors determine pumpability: viscosity and temperature and both need understanding."

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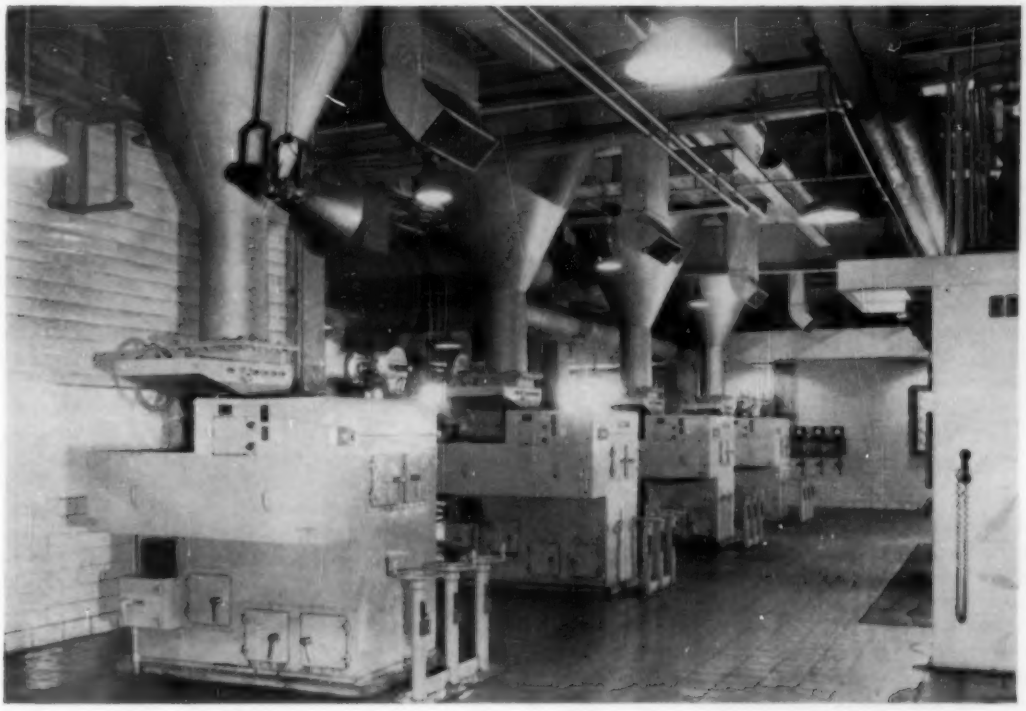


Fig. 1—Bunker noses installed in the Salem Harbor Station, New England Electric System, made up of $^3/_8$-in., 20 per cent, Type 304, stainless-clad steel have been in operation since September 1952 without a single hangup

Clad Steels Prove Economic for Coal-Handling Equipment

By MANOLO WIECHERS

Mechanical Engineer, Lukens Steel Co.

Hangups in coal pipes or chutes and arching in coal bunkers have been tackled over the years by everything from permanently installed rappers and vibrators to judiciously applied sledge hammers. Here is a current report on the advantages clad steel surfaces present in this instance.

Coal stoppage is a problem that today is beginning to assume greater and greater importance to the operator of a modern utility central station where any halting in the flow of coal to the boilers can have serious repercussions throughout the entire system because of the 100,000 or more kilowatts frequently supplied by just one generator.

Consequently, coal-handling equipment is currently subject to careful scrutiny by a number of leading operators not only due to the over-riding consideration of precluding coal stoppage but also due to the not inconsiderable expense involved in the repair and replacement of worn equipment in a crucial operating area.

As is well known, coal has three characteristics that cause hangups and wear out equipment fabricated of carbon steel: (1) sulfur, reacting with ever-present moisture, forms a weak solution of sulfuric acid that rapidly eats away carbon steel; (2) coal is abrasive, and as it flows over the rough, corroded surface, wear is intensified, often cutting equipment life to as little as one year, meanwhile, increasing hangups; and (3) moisture-laden coal fines, the amount greatly augmented by lot storage, have a tendency to pack.

This moisture proves the dominant factor in stoppages and the chief threat to equipment life. Its presence leads to two effects: physical (compacting) and chemical (corrosion). Together they accelerate the causes of stoppage and make its correction difficult.

Actually, there is a critical range of allowable surface moisture content, around 5 to 8 per cent, depending upon size consist of the coal where the static angle of repose increases sharply and with this a greater tendency toward compacting. Ratholing, arching and complete stoppage result with their attendant problems.

There is overwhelming evidence, particularly in these

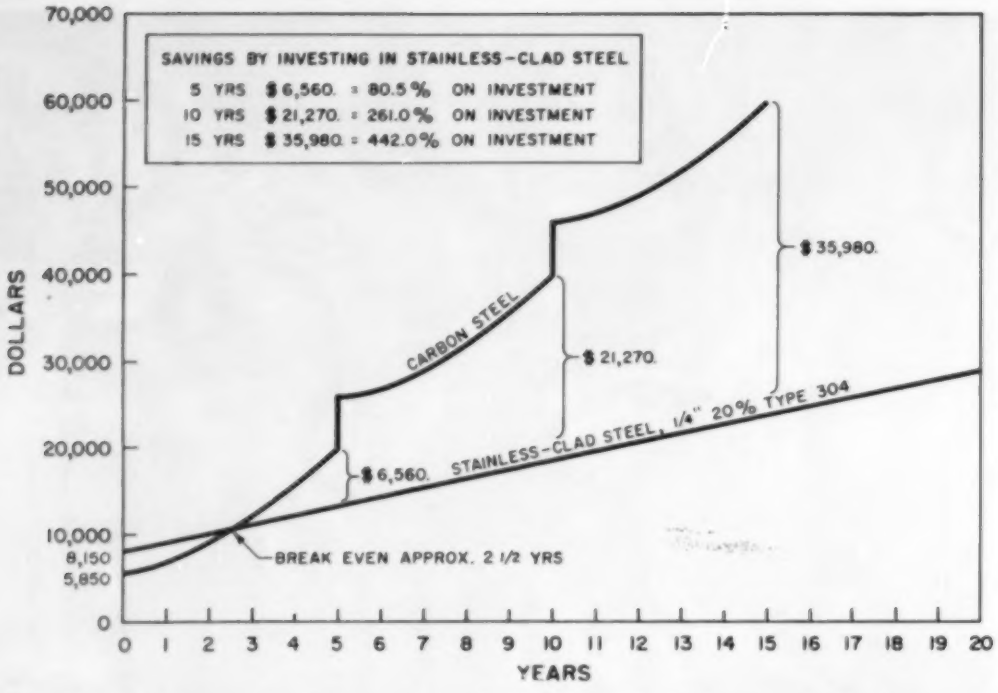


Fig. 2—Cost and maintenance records on hoppers, pipes and bunker noses compiled by one utility for both carbon steel and clad-steel members permit effective comparisons between the two materials by a plot of dollar outlays over the years

days of increased lot storage, that the performance of carbon steel coal-handling equipment fails on both counts of economy and operating service, Fig. 2.

Carbon steel is unquestionably the most expensive material that can be specified for this service. Its first cost is low, but continued maintenance at ever-increasing labor costs plus short service life make carbon steel an uneconomical specification.

The remarks of a generating station superintendent, who prefers to remain anonymous, could be echoed by many men in the field. He said, speaking of an installation, "These carbon steel coal pipes went into service between 1945 and 1948, and *all* of them are leaking like sieves. We started patching a year after installation, and as long ago as 1950 requested replacement of half of them—some only two years old at the time. We have been patching and hammering, and then patching again ever since to keep them in service, meanwhile badgering the engineering department to replace them."

Stainless Clad Steel

As a result of similar experiences a number of companies have switched in recent years from carbon steel to other materials for the surfaces of these critical parts. One of the most successful surfaces has been stainless clad steel of the 300 series—such as AISI Type 304. This material has excellent characteristics—is impervious to the attack of weak concentrations of sulfuric acid, and shows no measurable loss of gage—merely becoming highly polished—after many years of heavy service.

Clad steels were developed by Lukens Steel Company and The International Nickel Company, Inc., back in 1930 to permit industry to gain the many advantages of high-alloy materials in plate form at a lower cost. Broadly speaking, clad steel consists of a layer of costly high-alloy material permanently and integrally bonded under heat and pressure to a thicker, low cost carbon steel backing plate which supplies the needed strength. The thickness of the cladding is usually either 10 per cent or 20 per cent of the total thickness of the clad plate. Fig. 3 pictures a sample cladded plate.

Since in most industrial applications (and coal-handling equipment is a good example) a special surface is required only on one side of the equipment, clad steel fulfills its designed purpose of permitting the benefits of stainless steel surface to be obtained without payment for the full thickness of stainless.

Clad steel shows other superior characteristics for coal-handling equipment: an even interior surface and insurance against seepage which might occur if thin-gage linings were used. Uneven spots on thin-gage linings offer points of wear which when worn through permit corrosives to penetrate. Assuming, for example, stainless steel linings were used over carbon steel, any seepage would lead to rapid deterioration of the stainless, because of lack of oxygen between the lining and the base metal, as well as serious corrosion of carbon steel.

Operating Life

Some years ago, when the application of stainless steel was just being developed for coal-handling equipment the senior engineer of a large Eastern utility advised his management that the company would be justified in ordering stainless-clad coal hoppers and chutes—even if

they would cost three times as much as carbon steel—if, by so doing, service life could be no more than doubled.

Carbon steel coal chutes in use at this plant had a life expectancy of roughly three to three and one-half years, and were subjected to heavy maintenance and repair expense during practically that entire life span. Corrosion of the inside surfaces was responsible for many flow stoppages.

On the basis of this engineer's recommendations, a stainless-clad steel chute was installed in 1944 for test purposes. After five-and-a-half years' continuous service with bituminous coal, the chute was checked for wear. Inspection showed that the only effect of more than half a million tons of coal passing over the surface had been to polish it to a mirror-like finish. Profilometer readings showed between 6 and 7.5 micro inches—a high degree of polish comparable to that produced by lapping. Today this chute is still operating perfectly.

Even though this chute was not equipped with vibrators, the superintendent stated that he could not recall a single instance of stoppage. Unquestionably, the low coefficient of friction of the stainless steel surface had a definite bearing on eliminating the need for vibrating, sledging and lancing.

Four carbon steel feeder hoppers went into service on Boiler No. 63 of the Huntley Station of the Niagara Mohawk Power Corporation at Buffalo, N. Y. in 1942. By 1944 these hoppers had worn badly, and were causing hangups and stoppages. In 1945, one of these hoppers was replaced with a hopper fabricated of $^1/_4$ in. 30 per cent stainless-clad steel, Type 304, Fig. 4.

This hopper gave entirely satisfactory service. By 1947 the remaining three carbon steel hoppers serving this boiler had failed, and they too were satisfactorily replaced with stainless-clad steel.

This year examination was made of the interior of the first of these hoppers to be installed. During the nine and one-half years it had been in operation it was estimated that one-half million tons of coal had passed through the hopper. A sample was taken from an area of the hopper considered by Huntley Station engineers to be subject to the most severe service.

It showed the surface to be in excellent condition with no measurable evidence of wear or pitting from corrosion A smooth, high polish had been acquired eliminating apparently, any tendency of the coal particles to cling to the surface.

No measurable loss of metal was apparent. Hardness tests showed some surface hardening due to the cold-working effect of sliding coal.

Although cost and maintenance records are not usually kept on specific items of equipment such as hoppers, pipes and bunker noses, a leading utility has kept such records on a series of four coal pipes. This has been plotted on Fig. 2, and includes yearly maintenance costs, interest, depreciation, and replacement every five years. The anticipated cost of an identical clad steel installation has also been plotted on the chart. In this case, although the original cost would have been greater than carbon steel, the clad pipes would have saved $6,560 in the first five years, and a total of $35,980 in 15 years.

Conclusions

Stainless-clad coal-handling equipment has now been in continuous, trouble-free service for varying periods in more than 30 different major utility stations. Although it has been in service for periods as long as 12 years, its full life expectancy has not been determined. However, if the results of a dozen years' service during which it showed no wear, are conclusive, a conservative estimate would be that the stainless-clad equipment will last for the life of the boiler.

It is extremely difficult to predict with any finality the quality of the coals coming on the market in the future for the power generation field. But the present indications are that this fuel could very likely run higher in the characteristics that cause hangup and short operating life in coal handling equipment, namely sulfur and moisture content. Further, there is a growing tendency to employ more automatic handling and feeding devices in the movement of coal to the individual boilers in power plants now in the planning stage. Both of these possibilities point up the advisability of equipping coal pipes, chutes, and hoppers with the best available facilities for long life, and fewer operating difficulties.

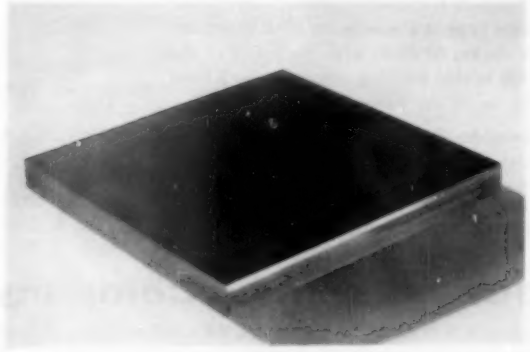


Fig. 3—A layer of 20 per cent stainless-cladding bonded by heat and pressure to a carbon steel backing plate. This material has proved applicable in power plants from coal bunkers to pulverizers or stokers and is said to give long life

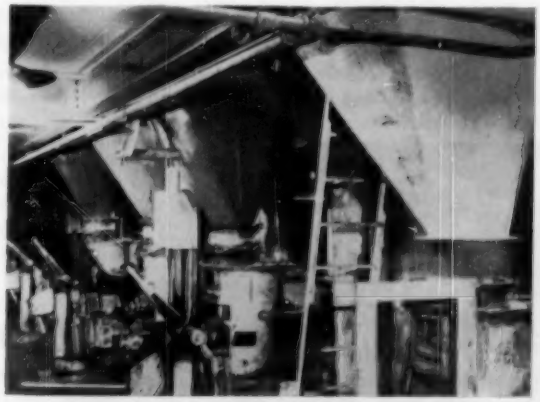
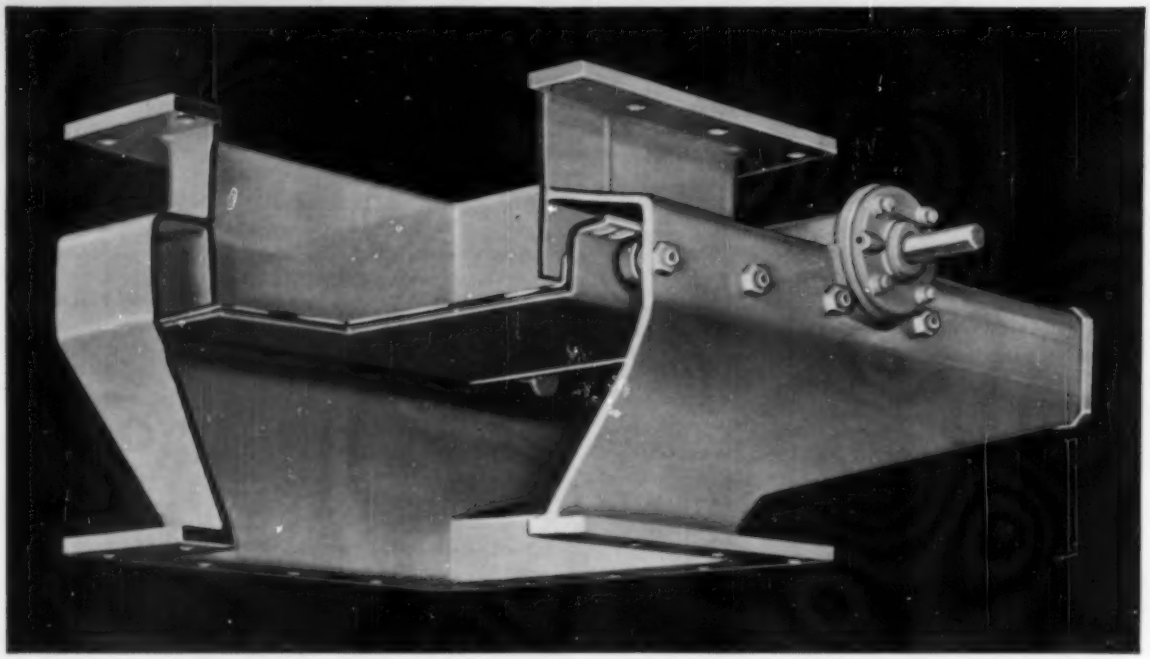


Fig. 4—A battery of four originally carbon steel feed hoppers had worn so badly one was replaced by a clad-steel unit in 1945. By this year all were clad steel and the first one of this material was in the labs for examination



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Atomic Energy—A Realistic Appraisal

UNDER the auspices of the Atomic Industrial Forum, Inc., a two-day meeting designed to appraise the current status of atomic energy in American industry was held at the Waldorf-Astoria Hotel in New York on May 23–24. Successive panels discussed nuclear research and development, reactor components, reactor fuels, and special problems of atomic energy, including marketing, legal considerations, and insurance. Throughout the meeting emphasis was placed on interpreting a comprehensive report recently prepared by the Atomic Industrial Forum, "A Growth Survey of the Atomic Industry—1955–1965."

Discussing personnel requirements for nuclear research and development, **Dr. V. L. Parsegian,** chairman of the engineering group at Rensselaer Polytechnic Institute, observed that training requirements at the Ph.D. level for physicists and chemists have changed inappreciably over the past few decades. Scientists with this training have been and will continue to be in short supply. He pointed out that an industrial company can effectively supplement its activities in the nuclear field by assigning to universities research projects which are too fundamental or too diverse or exploratory for the company's own staff to handle. Industry-college relationships of this sort are mutually beneficial in generating ideas and enabling the schools to graduate the type of engineers and scientists that companies may wish to employ.

With respect to personnel for designing atomic power plants, Dr. Parsegian expressed the belief that the vast majority of engineers required will be graduates of the familiar engineering curricula who have obtained sound experience in the professional specialty of their choice plus additional familiarity with the special problems and techniques of nuclear systems. He also pointed out that by far the most serious obstacle to the training job the colleges can do in the nuclear engineering field has been and continues to be the blanket of secrecy which shrouds atomic power development.

Responsibilities for Research

Discussing industry and government responsibilities for nuclear research and development, **Corbin C. Allardice,** executive director of the Joint Congressional Committee on Atomic Energy, stated that private industry has accepted the major rôle in the production of uranium ore and concentrates and is gradually accepting the major rôle in domestic exploration. The Government continues basic geologic exploration work as well as development of new and more efficient processes for milling and beneficiation of uranium ores. With respect to special nuclear materials, no private funds have thus far been invested in production facilities themselves, although some firms have invested in facilities especially designed for the fabrication of fuel elements. There are indications that this latter area may be among the first to offer economically attractive investments.

Atomic Locomotive

Bruce C. Gunnell, chief mechanical engineer of the Southern Railway System, prepared a paper entitled "An Atomic-Powered Railroad Locomotive" at the request of the atomic energy committee of the Association of American Railroads. While expressing disbelief in the justification of using an atomic-powered locomotive on American railroads within the next ten years, Mr. Gunnell felt that this type motive power might prove especially attractive in military service, primarily because of the advantage of having a locomotive that could operate without refueling for periods on the order of six months.

Reactor Components

According to **J. P. Magos,** director of engineering and research for the Crane Company, valve manufacturers do not anticipate any special tooling requirements to meet the needs of nuclear-fueled power plants. Among the technical problems that must be faced are those concerned with leak tightness, corrosion resistance and remote maintenance. Mr. Magos noted that one propulsion reactor employs valves that are remotely operated and will fail safe. He added that plans are being made to manufacture valves from such metals as titanium and zirconium at such time as they are required.

In the words of **A. M. Gegenheimer,** field project engineer of Blaw-Knox Company, piping, welding and inspection as a combined reactor component is something that too often is left to the end of engineering design and thereby receives minimum attention. He strongly stressed the desirability of giving more than an ordinary amount of engineering time to reactor piping installations, since properly engineered systems result in lower erection costs and a minimum of maintenance in a simplified design. Also it is possible to reduce capital investment as well as the required sizes of pumps and compressors through proper piping design.

While reactor piping installations have thus far mainly involved conventional materials, such as Schedule 40 and Schedule 80 seamless steel and Type 47 stainless steel, the installation of these materials poses new problems because of the stringency of the cleanliness requirements. Welding techniques, such as the heli-arc method, have had to be adapted to minimize oxidation, eliminate chemical slag deposits and reduce the area of weakness between the weld and the parent metal. New inspection procedures have also been devised for testing piping in nuclear installations, including the use of the acetoacetanilide test for free iron and the halogen leak detector.

David M. Schoenfeld, manager of the nuclear power division of Combustion Engineering, Inc., pointed out some of the differences between the fabrication of high-pressure reactor vessels and the type of pressure vessel normally manufactured by the boiler industry. For pressurized-water reactors, plate thicknesses approach the maximum that can be rolled; internal cladding with corrosion-resistant materials is required; and problems of cleanliness during fabrication, enormous weights for handling and chipping, and extremely close tolerances are encountered. Other types of reactors involve comparable, related problems of increased precision and special attention during the fabrication process. Mr. Schoenfeld stated that improvements in cladding and manufacturing techniques must be pursued to help decrease costs.

The cost of heat exchangers already produced or in production ranges from approximately $3 per kilowatt of heat capacity for a pressurized light water system to $20 per kilowatt of heat capacity for a sodium system, according to **John Cartinhour,** manager of the nuclear energy department of Foster Wheeler Corp. It appears reasonable to expect that these costs can be reduced to $2 and $10 respectively by 1964. Mr. Cartinhour strongly urged that design efforts in heat exhangers be directed toward compactness, simplicity and arrangement of equipment so that repairs may take place despite radioactivity.

Paper Abstracts From ASME Spring Meeting

The Diamond Jubilee Spring Meeting in Baltimore, Md., April 18–22, 1955, featured some 33 papers in addition to banquet and luncheon speakers. The following are abstracts of those papers held to be of interest to the power field.

Water Conditioning

"The Treatment of Condenser Circulating Water"

By **Dr. Ing. Andrea Iorio,** Societa Meridionale Elettricita, Naples, Italy.

After a few considerations of the degree of cleanliness of condenser tubes this paper proceeds to the examination of the effects of condenser water on the tubes and on the inlet equipment. These effects can be considered under the double aspect of incrustation and corrosion. Reference is partially made to the investigations conducted at the thermoelectric centers "Maurizio Capuano" and "Vigliena" of the Societa Meridiana di Elettricita to study the nature and behavior of incrustations and corrosion caused by the use of salt water from the Naples Harbor.

During the winter months, from November to March inclusive, when water is below 19 C, effective control was achieved by chlorinating four times daily. Each chlorination period was of one-half hour's duration, and at 0.5–0.6 ppm residual with dosage rates at 1–2 ppm.

During the summer months, from April to October inclusive, when the water temperature is about 19 C effective control required chlorinating twelve times per day. Each chlorination period was of 50 minutes duration and at a residual of 0.7–0.9 ppm with dosage rates of 6 ppm.

"Control of Slime and Marine Fouling"

By **S. A. Cole,** Wallace & Tiernan, Inc.

This paper covers modern slime and marine growth control practices using chlorination. The value of free chlorine residuals, time of contact, magnitude of residual, and frequency of treatment are discussed. Unusual case histories illustrated the influence of various external factors on chlorine treatment—for example, the presence of ammonia.

Properly applied chlorination according to the author, will control organic fouling of water tunnels, pipelines, and water-cooled heat-exchange equipment regardless of water source and type of cooling system. It is important that the capacity of the chlorinator installation be selected to provide a chlorine dose which will produce a free available chlorine residual of at least 1.0 ppm under extreme conditions. Special problems of pollution of water supply or marine growths may require that the operator experiment seasonally to determine the most effective treatment schedule. The chlorine solution distribution piping system and particularly the diffusors must be carefully designed for each installation. This is most important, if the control of salt water organisms is the primary purpose of the treatment.

Gas Turbines

"The Development of a 500-HP Multipurpose Gas Turbine Engine"

By **P. G. Carlson** and **I. M. Swatman,** Solar Aircraft Co.

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purpose gas-turbine engine became evident it was decided that the design modifications of the U. S. Navy's Jupiter Series gas turbine should provide for making either a single-shaft or two-shaft engine from substantially the same components. The two-shaft or split-wheel configuration, with its inherent torque-multiplication feature, is required for boat or vehicle propulsion, while the single-shaft version, with its high rotating inertia, is ideally suited for electric-generator drive, where sudden load changes can occur. The single-shaft engine was designated the Solar Jupiter T-520J, and the two-shaft version as the T-522J. At a later date, the multipurpose concept of the Jupiter Series engines was extended to include a version of the single-shaft engine wherein its useful output is provided in the form of compressed air, in addition to shaft power. The compressed air is bled from the discharge of the 10-stage axial-flow engine compressor.

From a survey of the field of applications, it appeared that the original prototype unit rating of 400 hp maximum was slightly low and that a unit with a maximum rating of 500 hp and a continuous rating of 420 hp would be more desirable for long-life applications. The basis for engine ratings in naval applications involving prime movers of this type has been established as 80 F air-inlet temperature with inlet and exhaust pressure losses of 4 and 6 in. of water, respectively. It should be noted that the emergency power and continuous power ratings become 590 and 500 hp when based on NACA standard day conditions with no inlet or exhaust pressure loss, the basis generally used for rating aircraft gas-turbine engines.

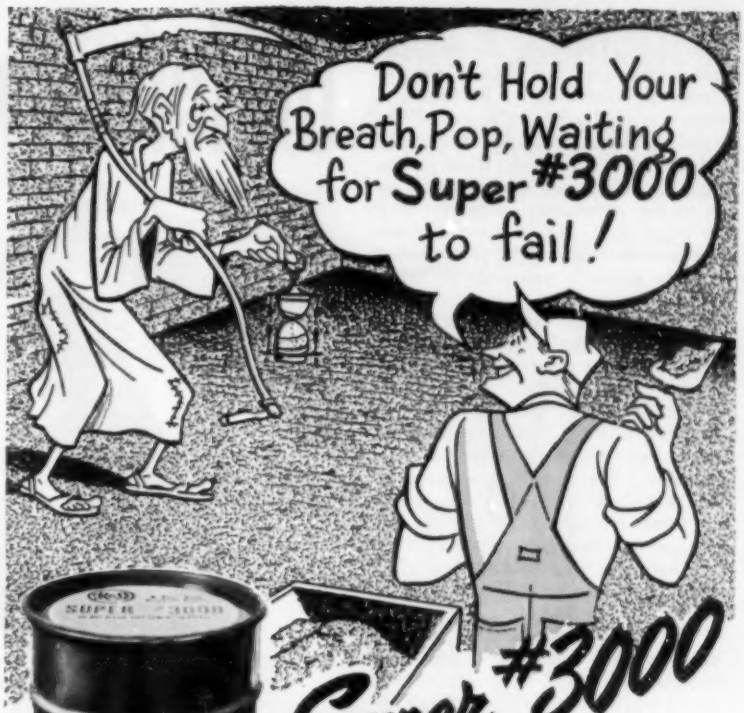
As emphasized in the original design conception of the unit, the power plants were designed for a minimum 5000-hr life. This consideration the authors feel seems a must when comparing the gas turbine with competitive, commercially available diesel power plants.

Nuclear Design

"Evaluating Basic Materials for Nuclear-Fueled Power Plants"

By **D. O. Leeser,** The Detroit Edison Company.

Reactors which are fueled with enriched uranium, or U-235, have been constructed and operated. However, converting the concentrated heat potential of this fuel into superheated steam, which in turn produces power, requires a complex plant. Included in the requirements for a plant, are the primary and secondary cooling



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systems, specially designed heat exchangers, critical and accurate control mechanisms, and built-in remote-handling facilities. Fortunately, there has not been any dearth of designs of nuclear reactors technically capable of producing electrical power. The problem has become one of balancing economic aspects with technical and design specifications.

One point of considerable interest was the author's comments on fabricating aspects.

"All machining work on fissionable materials, is performed in isolated boxes or in extremely well-ventilated hoods. This equipment not only protects the worker but also permits recovery of chips, turnings, and oxides from fuel materials right at the machine. The hoods are made so that a coolant or liquid vehicle carries all excess machinings into a pan and not on the working surfaces. Contaminated air and coolant are withdrawn from the hood, separated, and individually filtered.

The actual techniques of working uranium are standard fabrication processes modified to meet requirements imposed when handling radioactive materials remotely. Uranium can be machined; however, it oxidizes rapidly. When finely powdered, it is highly inflammable and its fires are capable of contaminating large working areas. Because of its reactivity with many gases, the melting of uranium must be done in vacuum, in an inert atmosphere, or under a flux of molten salt not reactive to gases. Its melting temperature (approximately 2000 F) combined with its corrosive nature when molten, requires the use of high-temperature ceramic containers and special mold materials during melting and casting."

"The Use of Benzene as a Thermodynamic Working Fluid for a Nuclear Power Plant"

By **I. G. McChesney,** Rochester Gas and Electric Corp., and **R. H. Shannon,** United Engineers and Constructors, Inc.

The desirability of eliminating the possibility of a chemical reaction between water and radioactive sodium or eliminating the need and cost of a secondary coolant system to serve as a buffer between water and radioactive sodium, make it seem worth while to expend some effort in studying and evaluating other systems or thermodynamic working fluids. However, based on the study as outlined in this report, it is felt that the use of benzene as the thermodynamic working fluid is not warranted for the following reasons:

1. Even though actual plant cost data were not developed, it appears that a benzene plant may well be as expensive as the combined cost of the steam plant and the NaK coolant system.

2. The use of benzene involves additional hazards in the operation and maintenance of the plant. Certainly it is true that hydrogen-cooled generators are operated satisfactorily; however, the benzene hazard would be much more severe due to the large number of pieces of equipment, valves, and piping systems in the benzene power plant.

3. The potential danger of moderating elements, carbon and hydrogen, getting into the sodium coolant still exists with the use of benzene; thus resulting in an extremely hazardous condition with a fast neutron reactor.

4. The undesirability of having to tie the development of a benzene power plant in with the development of a nuclear reactor poses problems.

Owing to the fact that the heat-transfer properties of benzene (liquid and vapor) are not as good as the heat-transfer properties of water and steam, the heat-transfer surface area requirement for a benzene boiler will be greater than a boiler for water and steam. Therefore, the benzene boilers would be larger and cost more than steam boilers.

The same factors as noted under boilers on heat-transfer properties apply to the condenser and feed heaters for benzene. A benzene heat exchanger will be larger and cost more than a steam unit for the same duty requirement.

Since superheat in the benzene vapor represents a larger portion of the total heat to be removed in the condenser than in the case of condensing steam with a corresponding degree of superheat, it is necessary to desuperheat the benzene vapor from a heat-transfer standpoint. In addition, it is necessary to desuperheat the benzene vapor to minimize thermal stress and expansion problems in the condenser.

Benzene is very inflammable; therefore, it would be necessary to use an inert-gas system for sealing the turbine shaft, valve stems, pump shafts, and liquid valve discharge lines with benzene recovery equipment, or pipe the discharge lines to the condensers.

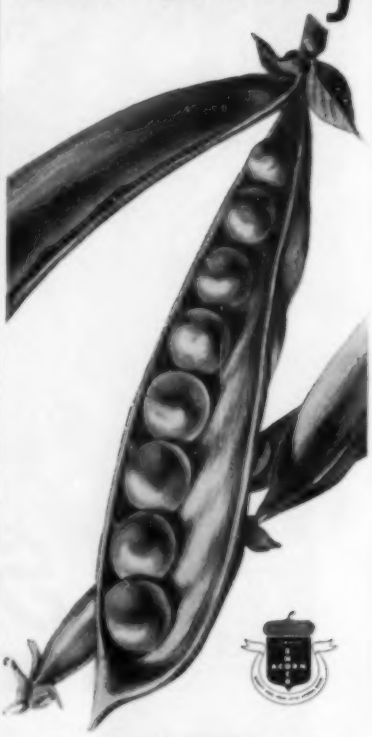
Water Conditioning

"Is Chemistry in the Power Plant an Exact Science?"

By **F. U. Neat,** Consolidated Gas Electric Light & Power Co. of Baltimore

The art of feedwater and boiler water chemistry can be divided into three classes. The first class believes that if water can be made pure

Uniformity



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enough, and kept pure, it is a suitable feedwater. The second class believes that is is not worth the effort to produce such pure water; that keeping the water pure is beyond the realm of practicality; that pure water alone will dissolve iron and other metals and this class treats the water with chemicals to render the impurities innocuous and to reduce the ability of the water to dissolve metals. A third class is always hoping that someone will come along with a gadget which will cure all difficulties of the handling of water and production of steam from this water. This class is not well represented in the utility field.

One of the prime reasons why power station chemistry is misunderstood is that, when a paper is written propounding the benefits of any one chemical or system of chemicals in the power plant, while the truth may be told it is seldom that the whole truth is told. In some cases, this may be because the whole truth is not known. In other cases the whole truth is not told for publication but is conferred in confidence or in private. In either case, a false impression is given to those who are not versed in the chemical arts. For instance, those of us who chemically treat do not make widely known our troubles with hide out, sampling, and testing. Nor do we admit to harmful chemical breakdown. On the other hand, those who practice no treatment do not make widely known their difficulties with tube failures or do they treat the ammonia content of their steam as of any great importance.

The time-honored treatments of inhibiting caustic embrittlement was selected for discussion. Although this sort of trouble is rather rare these days, at least among the utilities and the railroads, it is not too well known whether the application of chemicals or better design of boilers has caused this reduction. There is much reason to believe that both have served. And, since embrittlement causes so little trouble now, studies may not be made and the argument would still exist.

The author then traced the major method of combatting caustic embrittlement and the theories behind them as well as some unanticipated operating problems they raised.

Water Conditioning

"Significance of Slime in Causing Corrosion and Mechanisms of Corrosion by Slime Growth"

By **R. S. Wise,** National Aluminate Corp.

This paper outlines the ways in

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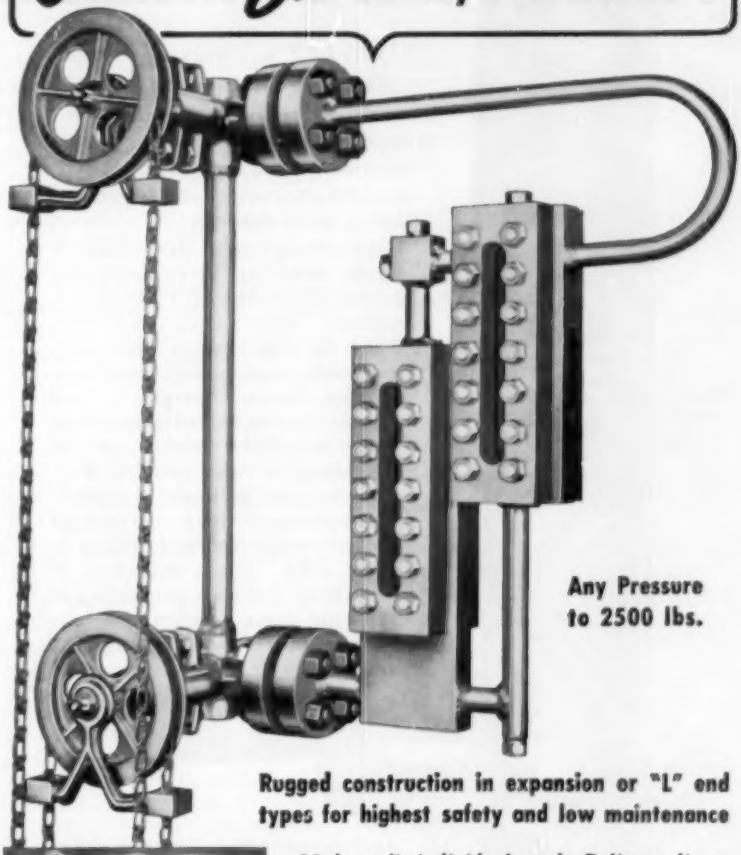

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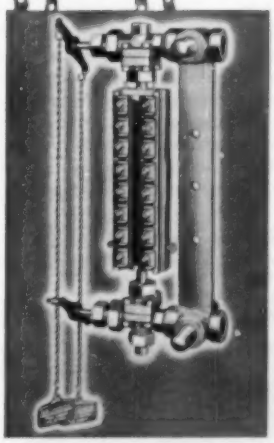

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which bacterial corrosion can take place in cooling-tower systems, and presents data under laboratory controlled conditions to illustrate the degree of corrosion which may be expected from this source.

The data presented show a definite adverse effect on corrosion rates of steel by the presence of microbiological growth. The degree of increase in corrosion may vary from 25 to 100 per cent according to these data. There is a possibility that even greater increase in corrosion rates due to microbiological growth could be obtained where mineral corrosion inhibitor is inadequate. Because of the localized attachment of slime growths, it is very probable that localized attack of steel can be expected with microbiological growth.

The degree of corrosion to be expected from this source certainly justifies good control of bacteria in a cooling-tower system from the standpoint of corrosion alone even if there were no other adverse consequences of the microbiological growth such as reduced heat transfer and restriction of water flow.

Condenser Design

"An Approach to the Economic Problem of Matching Condenser Surface with Exhaust Annulus Area"

By **W. A. Wilson,** MIT and **L. G. Malouf,** Convair Corp.

The separate tasks of selecting the appropriate condensing surface and the appropriate turbine exhaust annulus area for a given power plant are reduced to the single problem of selecting a balanced combination of these areas. This simplification is possible because the effects of each of these areas on operating cost and on plant capacity are made manifest by their influences on the same working fluid property; that is, the stagnation enthalpy leaving the last turbine blade row. At the same time, the remaining components of the plant are sensitive only to this enthalpy and not to variations of the combination of condensing and exhaust-annulus areas which establishes the enthalpy. This combination is balanced for the particular enthalpy. A balanced combination exists for each value of stagnation enthalpy.

Nuclear Design

"Selection of Materials for a Sodium Graphite Reactor System"

By **C. C. Woolsey, Jr.,** North American Aviation, Inc.

The sodium-cooled, graphite-moderated nuclear reactor system has been included as one of the five approaches to economic nuclear power

being sponsored by the Atomic Energy Commission. The heat is to be exhausted to the atmosphere through sodium-to-air heat exchangers. The reactor will generate about 20,000 kw of heat at temperatures near 1000 F. An advantage of this type system is that such temperatures can be obtained at normal atmospheric pressures.

The reactor core is contained within a tank, surrounded by shielding, all below ground level. Sodium is pumped to the lower chamber of the tank, upward through the reactor core to the upper chamber, then out to primary heat exchangers located in galleries external to the reactor itself. A secondary sodium system transfers the heat from the primary heat exchangers to the sodium-to-air heat exchangers. If a power-generating plant were to be included, the latter heat exchangers would be replaced with boilers for producing the steam necessary to drive the turbines.

The reactor core consists of a group of graphite moderator elements with fuel, control, and safety elements distributed within them. The graphite elements are canned in zirconium and supported by a lower grid. Other elements of the core are supported from the top shield and present either zirconium or stainless-steel surfaces to the sodium-coolant stream. The reactor will be fueled with slightly enriched uranium metal, encased in stainless steel. During the course of experimental operation the thorium-uranium-233 breeder fuel system will be examined for applicability in sodium-graphite reactors.

Design requirements specified a system which initially would operate satisfactorily with sodium at 1000 F, and one in which a minimum of modification would be necessary for operation up to 1200 F. Criteria for selection of materials for such a system include:

1. Suitable mechanical properties at the elevated operating temperatures.

2. Resistance to corrosion in high-temperature sodium, including transfer of radioactive elements from material in the core to surfaces in other parts of the system.

3. Absence of formation of low-melting eutectics as a result of metal transfer and diffusion, as well as the formation of alloys of poor corrosion resistance.

4. Constitutional stability of materials after extended times at elevated temperatures and in high radiation fields, and their effects on the foregoing considerations.

5. Minimum neutron cross section for materials to be included in the reactor core.

6. Ability to fabricate into required configurations.

7. Cost and availability.

From all considerations, other than neutron cross section, the austenitic stainless steels appear to be the most satisfactory for use in the sodium system. Since the relatively high cross section is costly in terms of increased fuel enrichment, a more suitable material was sought for those components to be located within the reactor core. Zirconium appears to be such a material; however, certain limitations exist with the zirconium available at the present time. These include, to some degree, elevated temperature mechanical properties, corrosion in high-temperature sodium, and cost. It is anticipated that research now under way will result in substantial improvements in these regards.

The author's main premise is, however, that progress has certainly been made and the future looks good.

"Shielding Concepts for Nuclear Reactors"

By **H. E. Stone,** General Electric Co.

This paper is an introduction to the problems associated with the shielding of nuclear reactors. All types of radiation present in nuclear reactors and their shields must be reduced by the shield to acceptable levels. Radiation of different types, neutrons, and gamma rays (high-energy X-rays) can be added in their biological effect and the sum must not exceed the AEC tolerance of 0.3 rem/week. All major sources of radiation encountered in reactor shields are discussed as well as three general types of shields. The three processes for reducing the number and intensity of gamma and neutron radiation are explained, followed by a discussion of of a typical shield calculation for a small source emitting S_0 particles per sec isotropically.

All major sources of radiation encountered in reactor shields were discussed as well as shield types.

The three types of shields mentioned were:

(*a*) The unit shield—for land-based reactors where weight and space are not of prime importance.

(*b*) The compartment shield—used in mobile reactors where a radioactive coolant and heat-transfer equipment are in a shielded area to reduce the total shield weight and size.

(*c*) The divided shield—which is the lightest of the three results in a large unshielded area between the reactor and personnel compartment.

The three processes for reducing the number and intensities of gamma and neutron radiation were explained. It was shown that neutrons require a light shield containing hydrogen (oil or water) while gamma rays need a heavy shield made of lead, for example a good shield design must contain neutron- and gamma-shielding materials and is, therefore, made up of oil or water plus steel or lead properly spaced.

"The Homogeneous Reactor Experiment"

By **W. R. Gall,** Carbide and Carbon Chemicals Corp.

In 1950 the Oak Ridge National Laboratory undertook the task of designing, building, and operating a pilot-model liquid-fuel nuclear reactor, the Homogeneous Reactor Experiment. The purpose of this plant was to investigate the chemical and nuclear feasibility of maintaining a nuclear chain reaction in an aqueous solution at a temperature sufficiently high for the production of electric power from the thermal energy released.

Some of the problems anticipated in the design were:

1. Radiation decomposes the water molecules into hydrogen and oxygen. Would the generation of these gas bubbles within the liquid core cause nuclear instability?

2. How could the hydrogen and

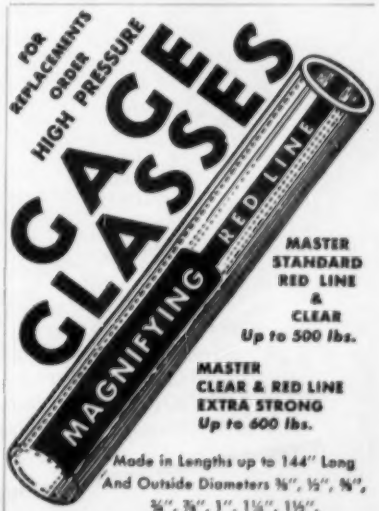

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FIG. 21—Lip Mold FIG. 22—Standard

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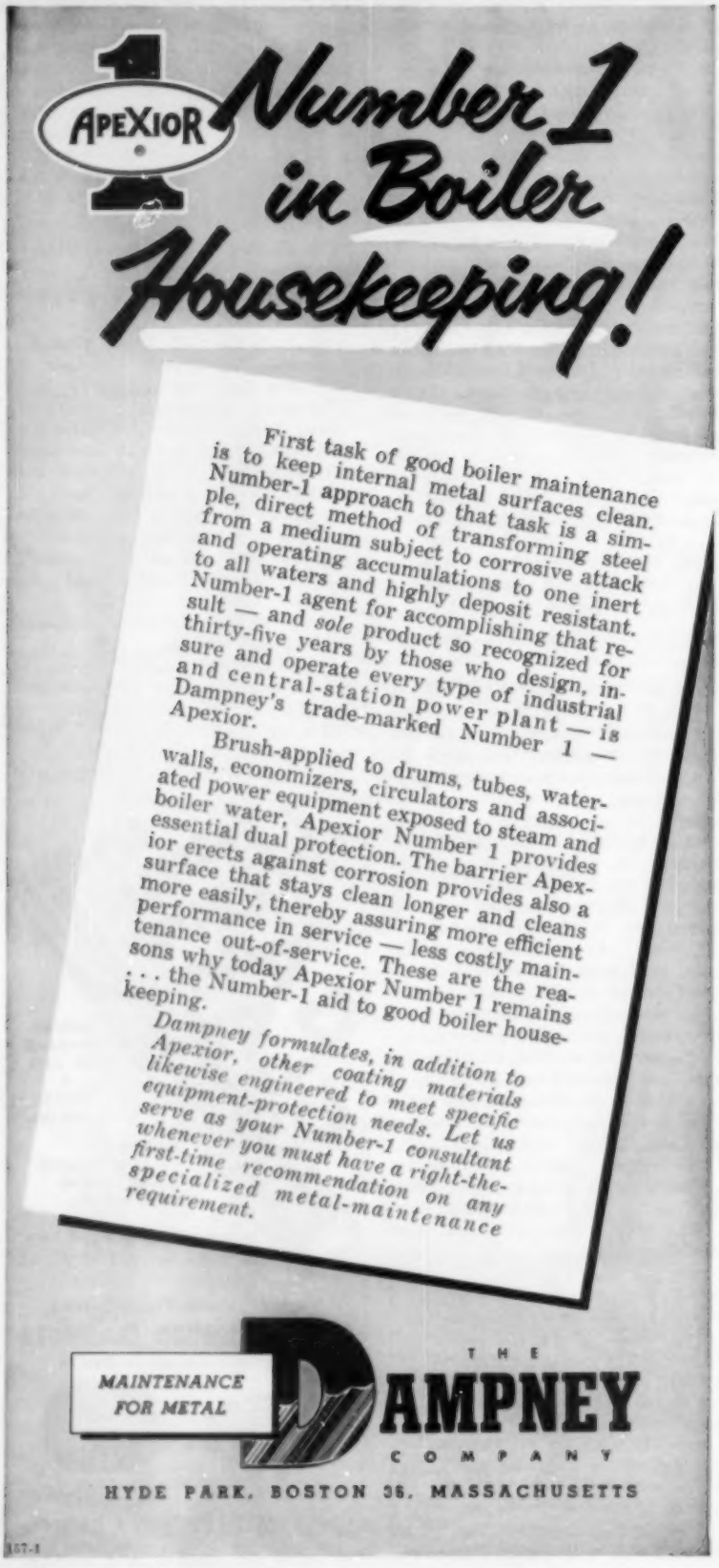
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oxygen produced by decomposition of water be recombined and returned to the system? It was estimated that the decomposition rate would be sufficient to convert all the water in the fuel solution to gas within a few hours.

3. It was expected that the reactor would have self-regulating properties. Would it be self-regulating as hoped, or would a fast-acting control system be required?

4. How would gaseous fission products be disposed?

5. How would leakage be kept low enough to prevent serious contamination and loss of valuable materials? The radioactivity of the fuel solution would be approximately 30 curies of gamma radiation per cubic centimeter. Hence permissible leak rates were of the order of magnitude of 0.1 cc of helium per 24 hr to 1 micron absolute pressure. The heat producing reaction occurred in an 18-in. diam spherical vessel and heat was removed by pumping the liquid fuel through a U-tube heat exchanger where steam was generated for use in a small turbogenerator unit. With the reactor generating 1000 kw of heat at 482 F and 1000 psi, 3000 lb of steam was produced per hr at 200 psia, generating 150 kw of electricity.

Designs of major items of equipment and the shield are described and the cost of construction is summarized. Throughout the entire paper the basic fact that fundamental data was still being collected was apparent.

Book Reviews

Energy Transfer in Hot Gases

The proceedings of a symposium held by the U. S. National Bureau of Standards on this subject on September 17–18, 1951, are published in this book. There are sixteen papers which were presented by scientists and engineers from a number of countries. The subject matter was generally of a highly theoretical character.

Some of the topics covered include electronic excitation in relation to flame spectra, studies of polyatomic flame bands, spectroscopic studies of low-pressure combustion flames, infrared emissivity of diatomic gases, present position of the theory of flames, reactions of atomic hydrogen in flames and concept of temperature by an astrophysicist.

Issued as National Bureau of Standards Circular 523, the buckram-bound book contains 126 pages, 54 figures, 15 tables and sells for $1.50.

This ring has been in service six months...

BUT WHERE'S THE SLAG?

The answer is simple. There isn't any.

That's because the burner ring, like two others in this central station, is made of CARBOFRAX® silicon carbide refractory. After six months of operation, the surface of the CARBOFRAX segments is practically as smooth as the day they were installed. As a matter of fact, this utility is so conscious of the problem of slag accumulation that they have lined the boiler wall between the burner rings with CARBOFRAX brick, too.

Silicon carbide won't soften, no matter how high the temperature inside the boiler goes. Slag can't fuse to its hard, dense surface . . . can't build up and deflect the flame . . . can't drop off in heavy chunks to harm the tubes below. And naturally, without accumulated slag to be barred off, there's no risk of damaging the refractory during routine maintenance.

CARBOFRAX burner rings resist abrasion by coal, as well as heat shock and flame erosion — even an out-of-line burner has little effect on them. Like to find out more about how these remarkable refractories can increase *your* firing efficiency? . . . Write today for our free booklet, "Super Refractories." Address Dept. E75, Refractories Division, The Carborundum Company, Perth Amboy, N. J.

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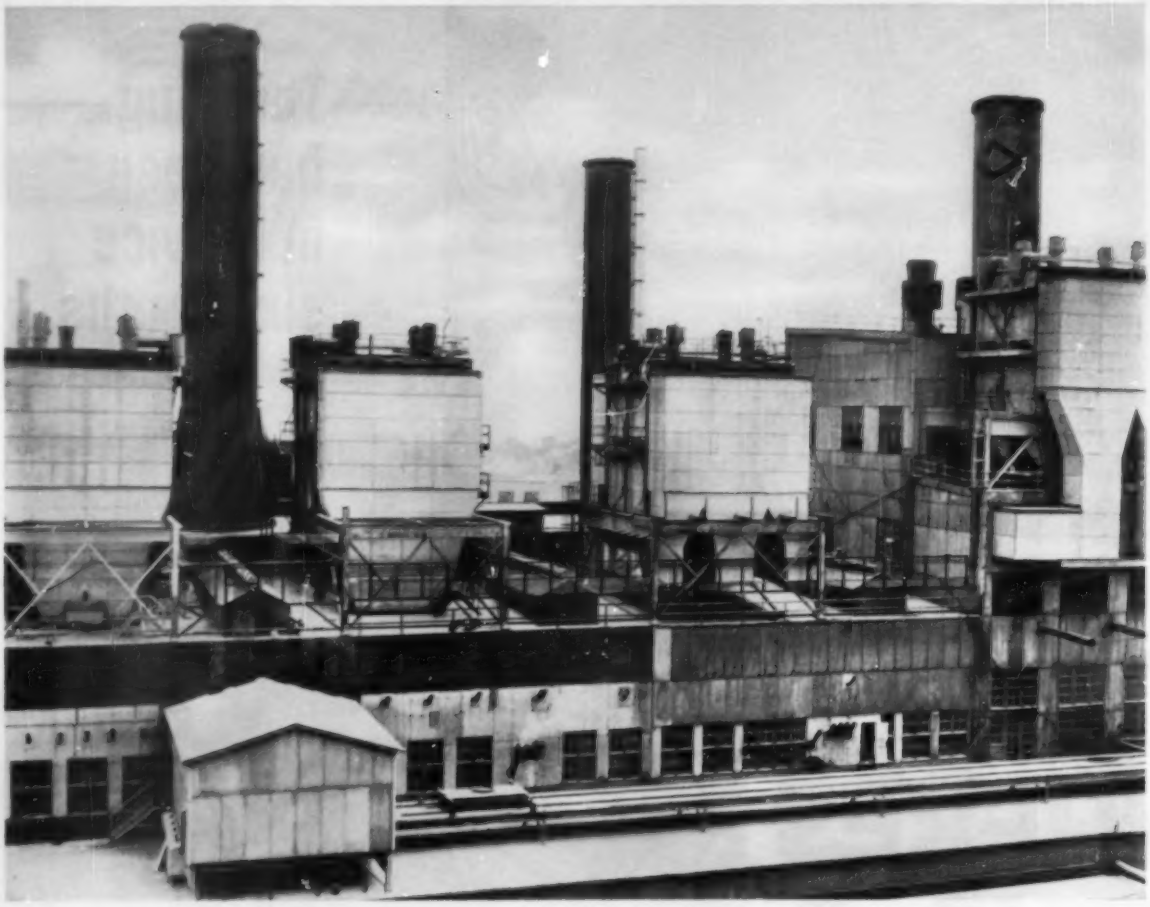

4 Koppers Electrostatic Precipitators exceed guarantee in fly ash removal for Diamond Alkali

Air pollution from the power house is no longer a problem at the world's largest alkali manufacturing plant in Painesville, Ohio. Four Koppers Electrostatic Precipitators atop the boiler house roof at this huge Diamond Alkali plant remove 95% to 97% of the dust normally discharged from the boiler plant stacks.

These Koppers Electrostatic Precipitators went into operation in 1954. Previously, the four plant boilers which vary in capacities—fired with pulverized fuel—had created a nuisance with stack gases containing a high fly ash content. Today, the four Koppers units with a total capacity of over 700,000 cubic feet per minute, trap and remove this fly ash, storing it in collecting hoppers before it is sluiced away to a waste lake.

Koppers engineers determined the most practical and economical precipitator size for each boiler—insuring Diamond Alkali the same high efficiency performance that makes Koppers Electrostatic Precipitators the finest.

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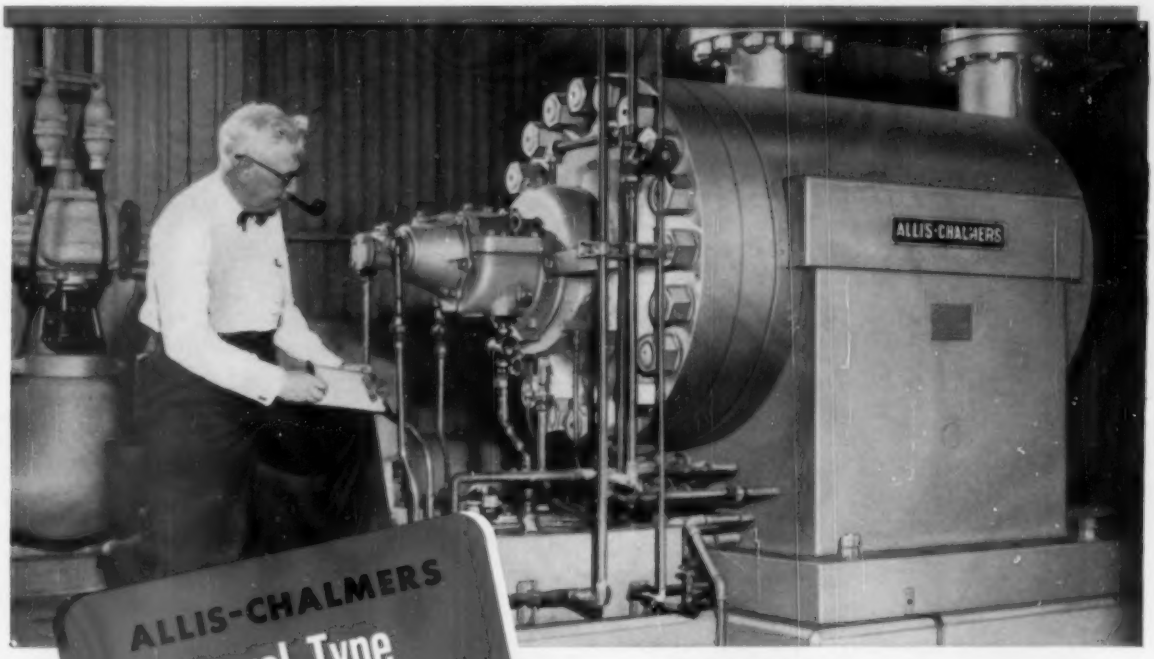

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Allis-Chalmers can supply the complete pumping unit—pump, motor and control—of coordinated design and manufacture. You get one responsibility—one guarantee of satisfaction.

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Here Are Important Features that Keep Operating Costs Low:

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- Double volute casing maintains radial balance under fluctuating load.
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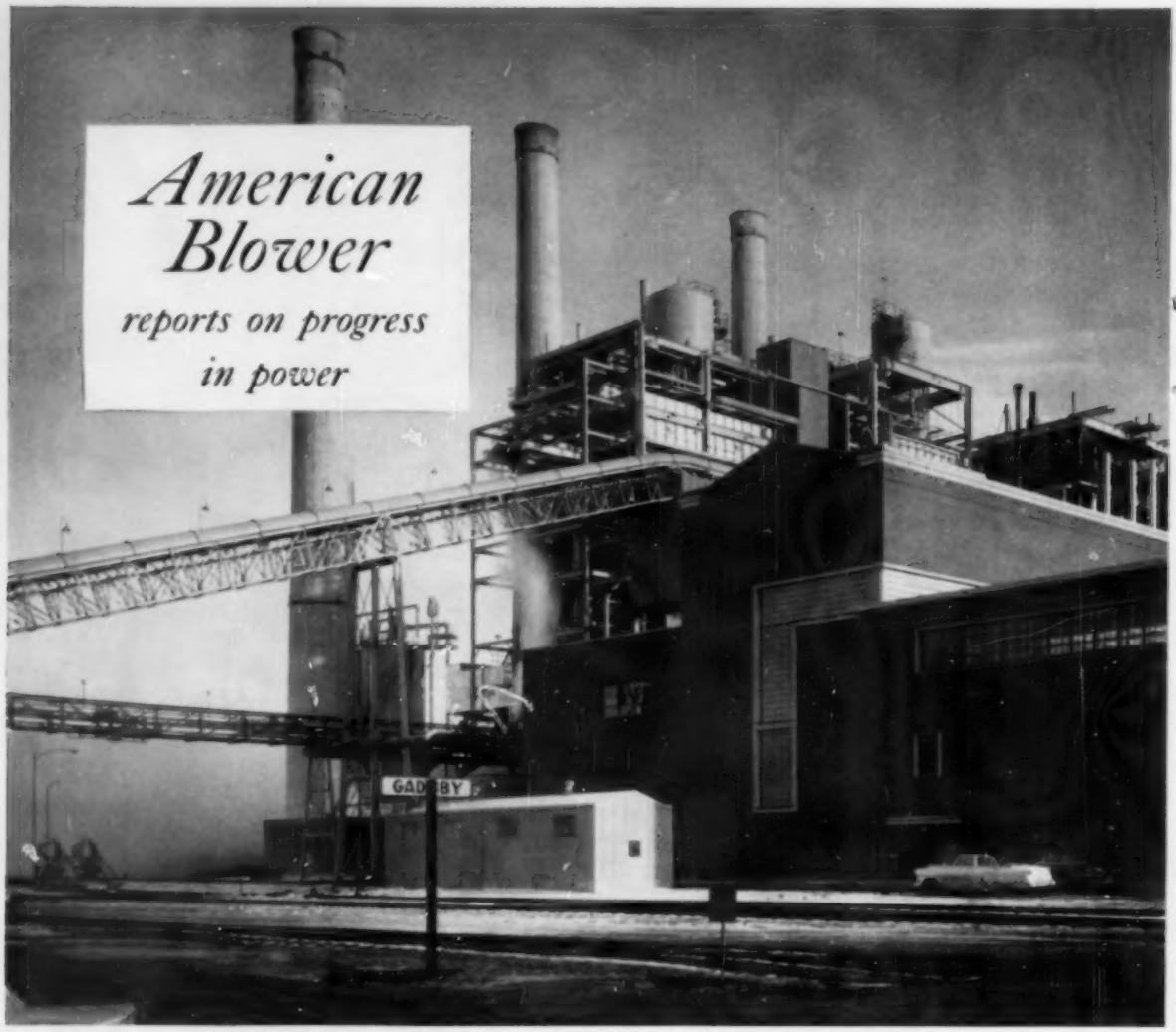


Gadsby Plant, located on the outskirts of Salt Lake City, is the largest steam-electric generating station in UP & L's system.

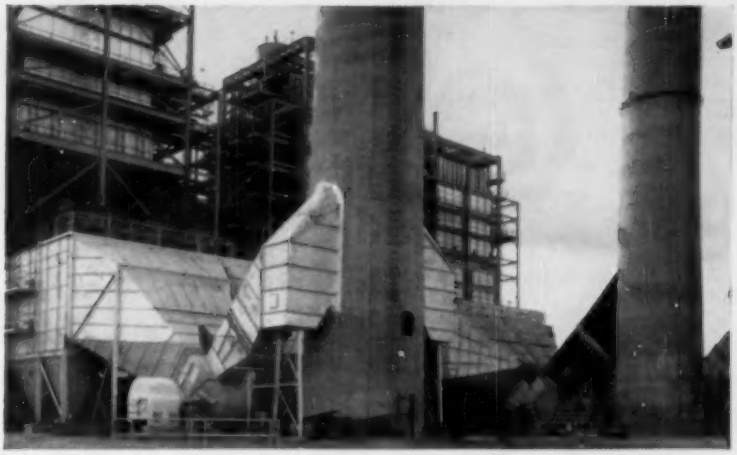
Utah Power & Light doubles capability

IN THE VAST Utah-Idaho-Wyoming-Colorado area where the Utah Power and Light Company serves some 700,000 people, raw minerals and chemicals are in abundance. Industries' influx to develop these natural resources is increasing at a rapid rate. So much so, that to keep ahead of rising electrical needs, UP & L has more than doubled its generating capability in the past 10 years to over 620,000 kw – and the end is not in sight!

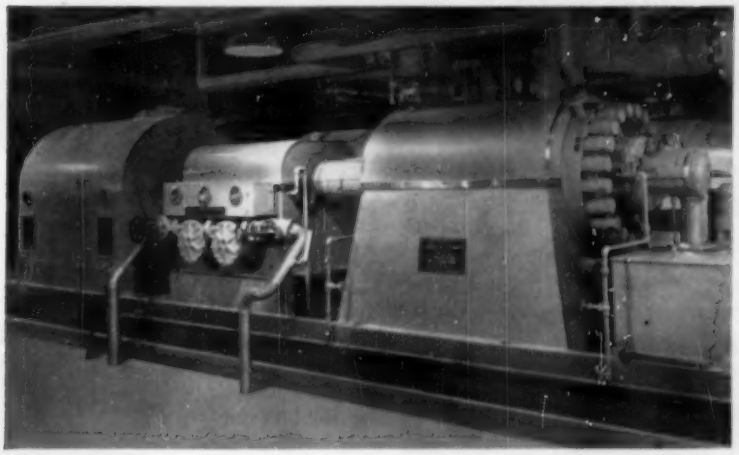
Costing upwards of $109 million, UP & L's new and improved electrical facilities include – at its Gadsby Plant – a new 100,000 kw steam-electric generating unit which utilizes the reheat cycle. As a part of this efficient operation, American Blower Sirocco Induced Draft Fans, Gyrol Fluid Drives, and Gas Recirculating Fan were selected.

The important part American Blower plays in UP & L's expansion program is being duplicated in dozens of other progressive, investor-owned companies. Utility men across the nation depend on American Blower Mechanical Draft Fans, Fly

Serving home and industry: AMERICAN-STANDARD • AMERICAN BLOWER • CHURCH SEATS &



Completed in June 1955, UP&L's new 100,000 kw No. 3 unit (left) boosts Gadsby Plant capability to 241,000 kw. The unit's two American Blower Sirocco Induced Draft Fans are each rated @ 260,000 cfm @ 325° F @ 15.5" sp @ 860 bhp. American Blower equipment is also installed on units No. 1 and No. 2.



American Blower Type VS, Class 6 Gyrol Fluid Drives provide adjustable speed control of boiler feed pumps at Gadsby Plant. Rating is 2500 hp @ 3600 rpm.

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. . . One leading public utility has a 4,500 psi, 1,150F double reheat cycle unit under construction. Another announced plans for a new supercritical pressure, steam electric station. The single-boiler-turbine-generator unit for this new station will operate at a higher steam temperature and pressure, and will have a capability greater than any installation thus far announced. Using supercritical pressure, and employing two stages of reheat, the new unit should be the most efficient plant thus far projected by the central station industry. The 6,[illegible] psi steam generator will supply steam to the turbine at 5,000 psi, 1,[illegible]00F. . . .

AS POWER PIPING BECOMES MORE CRITICAL

M. W. KELLOGG TESTING TECHNIQUES KEEP PACE

To meet the demand for more electric power, and to increase output with the least possible increase in fuel, the trend in utility steam power plants, as reported everywhere, is to higher temperatures and pressures. Thus steam piping—main and reheat—becomes even more critical than before.

One way in which The M. W. Kellogg Company, leading fabricator of power piping, keeps pace with increases in temperature, pressure, and capacity demands is in its testing techniques. Most recent Kellogg development is the company's "atomic camera". Activated by isotopes such as cobalt, iridium, and cesium, this powerful and portable device can photograph welded seams up to six inches thick in a single, short exposure. The same test by traditional X-ray equipment would take considerably longer.

The M. W. Kellogg Company was among the first to be permitted by the AEC to use isotopes of this magnitude. The atomic camera has already proved its value in the construction of many important public utility jobs. It is indicative of the Kellogg research and engineering which guard the vital link between steam power plant boilers and turbines.

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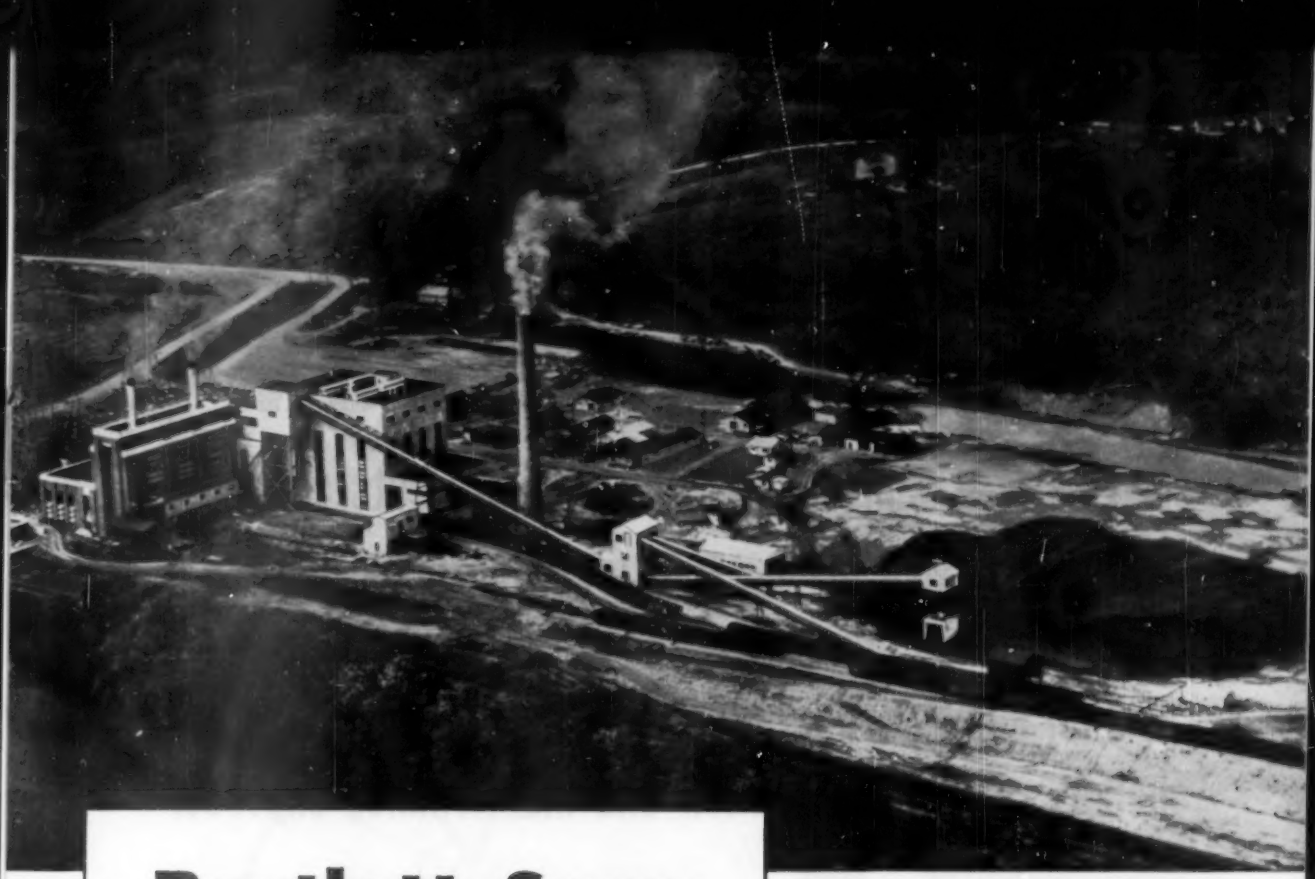

General View of Bremo Plant
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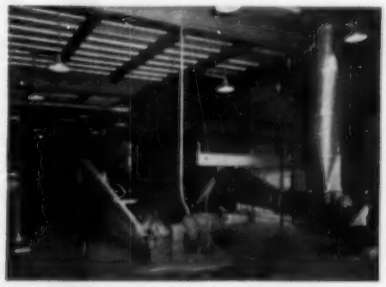
Bartlett-Snow coal handling at *Bremo*

● The illustration above shows both the original building and the new addition of this 60,000 KW plant. All equipment including the track hopper, duplex feeder, 1326′ of belt conveyors, the 70′ dust tight flight distributor in the new addition, and the 111′ distributing belt and belt driven tripper in the original building were detailed and fabricated in our shops and installed by us to Stone and Webster's specifications. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers, work with you on your next job.



View of Dust Tight Flight Conveyor
Distributing Coal to Bunkers (New Addition)

View of Belt and Belt Driven Tripper
Distributing Coal to Bunkers (Old Building)

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We have a new lot of coal and it clinkers badly. He's digging the clinkers out and covering up holes in the fuelbed.

Don't holes in the fuelbed make clinkers?

They sure do! And the air required for combustion goes through these holes and we can't keep the steam pressure up.

Why did we buy such coal?

Well, it was a few cents cheaper and we didn't consider the analyses so nobody realized it had such a low clinkering temperature.

So we save pennies on the coal and blow dollars up the chimney!

Yes sir! That's about the size of it. But just as soon as this lot is used up, we're going back to the old coal. That was specified for us by the Chesapeake and Ohio Fuel Service Engineers to give us the lowest *steam cost* with our type of stoker and boiler. We should have stuck with the coal they recommended — it never gave us a bit of trouble.

P.S.

There's a lot more to buying coal than the cost per ton. For facts and figures to solve your particular fuel requirements, write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake & Ohio Railway Company, Terminal Tower, Cleveland 1, Ohio.

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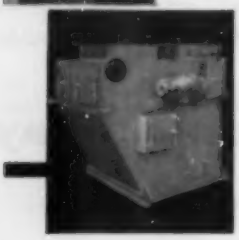

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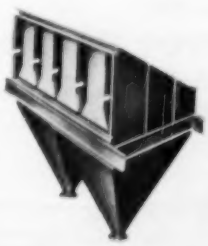

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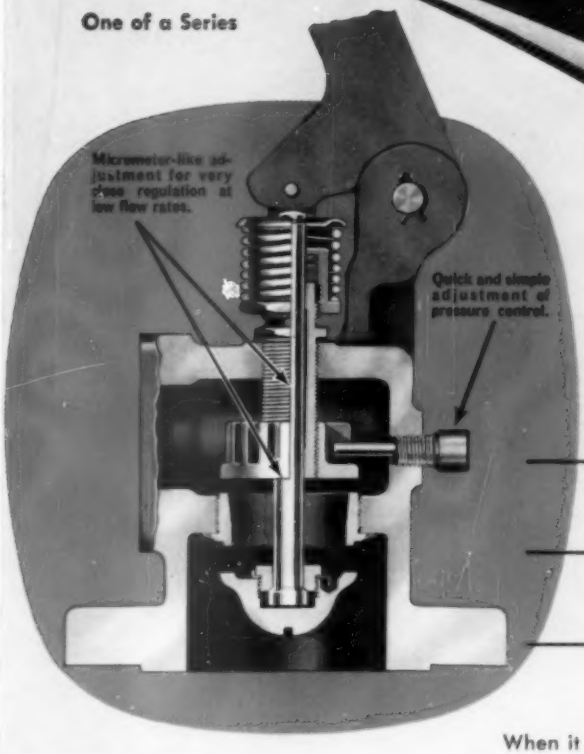
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Quick and simple adjustment of pressure control.

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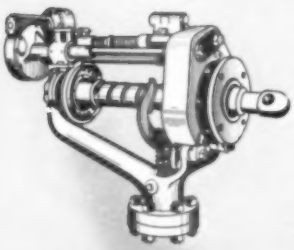
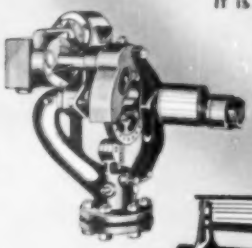
The Adjustable Pressure Control is one of a number of features of Diamond Blowers which provide better boiler cleaning at lower cost. It is standard on Models G9B, IR and IK. Write for Bulletins.



Diamond Model IR
Short Retracting Blower

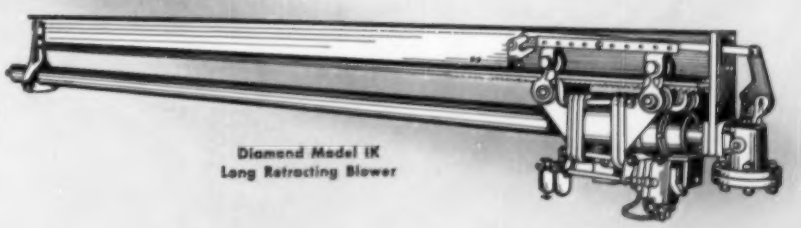


Diamond Model G9B
Automatic Valved Blower

DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

Diamond Specialty Limited, Windsor, Ontario



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4775

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Philip Sporn, president of the American Gas and Electric Company, whose planning, leadership and vision have made the history-making project at Philo a reality.

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